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Summary

This Article, excerpted from Michael B. Gerrard & John C. Dernbach, eds., *Legal Pathways to Deep Decarbonization in the United States* (forthcoming in 2018 from ELI), asks why household behavior matters for deep decarbonization, and how laws, policies, and programs that target behavior change can be employed to facilitate decarbonization. The pathways set forth in the Deep Decarbonization Pilot Project (DDPP) all presume widespread public acceptance of new policies, as well as changes in household actions that directly affect carbon emissions, mainly via consumer adoption of technologies that have lower greenhouse gas footprints. The best available research indicates that achieving the rates of adoption included in the DDPP pathways is indeed feasible; however, this will require more than policies that require change or make adoption financially attractive. The most realistic analysis of the potential for change must consider the technical potential for change, the behavioral plasticity, and the policy plasticity, or the feasibility of adopting and implementing the most commonly recommended interventions.

I. Introduction

This Article asks: why does household behavior matter for deep decarbonization, and how can laws, policies, and programs that target behavior change be employed to facilitate decarbonization? Individuals and households can affect carbon emissions in multiple ways through their behavior as environmental activists, by offering support or opposition to environmental public policies in their citizen roles, by exerting influence within organizations of which they are a part, by making investment decisions based on carbon considerations, and by acquiring and using energy and carbon-emitting goods and services or meeting their needs in ways that do not emit greenhouse gases. Each of these roles can be critical for achieving deep decarbonization. Our primary, although not exclusive, focus is on the roles of individuals and households as consumers, both of energy and of goods and services that have carbon footprints through their life cycles.[1]

The Article explores the implications of insights about behaviors affecting individual and household energy use, particularly from the noneconomic social and behavioral sciences,[2] for legal and policy interventions intended to achieve the goal of the Deep Decarbonization Pathways Project (DDPP)—the reduction of net U.S. greenhouse gas emissions by at least 80% from 1990 levels by 2050.[3] We examine the role that such behavior plays (explicitly and

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1. *See* Paul C. Stern, *Toward a Coherent Theory of Environmentally Significant Behavior*, 56 J. Soc. Issues 407, 407-24 (2000); Michael P. Vandenbergh & Benjamin K. Sovacool, *Individual Behaviour, the Social Sciences, and Climate Change*, *in* Climate Change Law, Elgar Encyclopedia of Environmental Law 92 (Daniel Farber & Marjan Peeters eds., Edward Elgar Pub. 2016); Thomas Dietz et al., *Household Action Can Provide a Behavioral Wedge to Rapidly Reduce US Carbon Emissions*, 106 Proc. Nat'l Acad. Sci. 1842, 1842-45 (2009).
2. Consumers are influenced by the prices of the goods and services they may acquire, but these are not the only important influences, nor do consumers process price information in quite the ways simple economic analyses might expect. National Research Council, Energy Use: The Human Dimension (Paul C. Stern & Elliot Aronson eds., 1984); National Research Council, Improving Energy Demand Analysis (Paul C. Stern ed., 1984). *See also* Richard H. Thaler & Cass R. Sunstein, Nudge (2d ed. 2009).
3. James H. Williams et al., Energy and Environmental Economics, Inc. et al., US 2050 Report, Volume 2: Policy Implications of Deep Decarbonization in the United States (2015) [hereinafter US 2050 Report, Volume 2]; James H. Williams et al., Energy and Environmental Economics, Inc. et al., US 2050 Report: Pathways to Deep Decarbonization in the United States (2014) [hereinafter US 2050 Report], *available at* http://deepdecarbonization.org/wp-content/uploads/2015/09/US_DDPP_Report_Final.pdf. *See also* Alexander E. MacDonald et al., *Future Cost-Competitive Electricity Systems and Their Impact on US CO_2 Emissions*, 6 Nature Climate Change 526, 526-31 (2016), *abstract available at* http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2921.html#close.

implicitly) in the four DDPP pathways, and we explore additional opportunities for behavioral interventions to contribute to achieving deep decarbonization.

We should be clear at the outset about what we include in the category of "behaviors affecting individual and household energy use." In short, we include both the adoption or uptake of household technologies and equipment, and the use and maintenance of technologies and equipment, in ways that affect emissions of greenhouse gases. As elaborated elsewhere,[4] seven specific classes of household behavior can affect carbon emissions. Some of these involve changes in the use of household equipment that reduce energy consumption by reducing energy services—what is often called energy conservation but is more appropriately called curtailment.[5]

These include changing daily behaviors regarding heating and cooling levels, appliance and motor vehicle use, and so on (D), and adjusting the water temperature in home equipment (A). Others reduce consumption without curtailing energy services, through better equipment maintenance (M); adoption of home weatherization and more efficient heating and cooling equipment (W); shifting to more energy-efficient motor vehicles and major household equipment other than space conditioning (E); and adopting renewable energy technologies for the household (R). Households can also, given appropriate information, make choices that reduce the life-cycle emissions (L) embodied in the goods and services they purchase. Unless otherwise noted, when we refer to "behavior," we mean individual and household behavior of the above types.

The factors affecting individual and household behavior differ per behavioral type, as noted below. Also, the opportunities for behavior change vary with time scales. On an immediate time scale, changes in usage of existing equipment (D and A) may offer the most effective steps toward deep decarbonization. Over a decade or two, adoption and use of lower emission equipment and acceptance of new technologies and energy policies and programs can often make the greatest difference. On the time scale of a generation or more, changes in lifestyles, social organization, built infrastructure, and public acceptance of major policy directions may be critical to achieving deep decarbonization goals.[6] Our focus is on individual and household behavior, but many social and behavioral science insights are also important for understanding the behavior of corporations, small businesses, government agencies, and other organizations at these time scales.

Although the DDPP focuses on the emissions reduction target for 2050, the carbon emissions pathway between now and 2050 will have an important effect on the ability to limit temperature increases to 2°C over pre-industrial levels, the ultimate goal of deep decarbonization. If U.S. emissions are higher than expected between now and 2050, an 80% reduction in 2050 will be inadequate; if they are lower than expected, there may be some play in the timing or magnitude of the 2050 goal.[7] As a result, we also examine the role of near-term behavior change in the DDPP modeling and how additional near-term behavior change can accelerate emissions reductions.

It is important to recognize that governments are not the only organizations that can drive the kinds of behavior change necessary to achieve deep decarbonization. Private and public initiatives have played important roles in energy behavior change in recent decades, and here we examine the potential roles of both public and private governance in achieving the behavior changes that can contribute to deep decarbonization. By private governance, we mean the performance of traditionally governmental functions (e.g., reducing negative externalities, promoting creation or management of public goods) by private organizations.[8] Private governance occurs through many of the same instruments as public governance, including prescriptive rules, market-leveraging approaches, and informational governance.[9]

In the area of climate-relevant behavior, private organizations conduct public information campaigns and training programs regarding efficient driving behaviors, and many private organizations are involved in energy or carbon labeling programs that affect the acquisition and use of more efficient equipment. Private organizations also set and monitor standards for sustainable fisheries, forestry, coffee, bananas, palm oil, and many other products.[10] In many cases, these private standards and certification organizations provide information that enables individuals to reduce their carbon footprints outside the areas of new technology acquisition by facilitating their ability to select various types of low-carbon goods and services and their ability to use these goods and services in more efficient ways.

As a result, when we refer to "laws, policies, and programs" in this Article, we include these types of governance

4. Dietz et al., *supra* note 1; Kimberly S. Wolske & Paul C. Stern, *Contributions of Psychology to Limiting Climate Change: Opportunities Through Consumer Behavior*, *in* Psychology and Climate Change: Human Perceptions, Impacts, and Responses (Susan Clayton & Christie Manning eds., forthcoming 2018).

5. Paul C. Stern & Gerald T. Gardner, *Psychological Research and Energy Policy*, 36 Am. Psychologist 329, 329-42 (1981).

6. *See* Paul C. Stern et al., *Opportunities and Insights for Reducing Fossil Fuel Consumption by Households and Organizations*, 1 Nature Energy (2016), *abstract available at* https://www.nature.com/articles/nenergy201643.

7. In other words, the shape of the emissions curve over the next several decades matters. It is only with reductions that begin in the near term that an 80% emissions reduction will suffice, and even then, emissions will need to be negative within the several decades after 2050 if 2°C is the goal. For a discussion of the mitigation efforts necessary to achieve the 2°C goal, see Michael P. Vandenbergh & Jonathan Gilligan, Beyond Politics: The Private Governance Response to Climate Change ch.2 (forthcoming 2017).

8. In the past several decades, successful climate and energy behavior change initiatives have been undertaken by governments at all levels, but also by corporations, advocacy and civic groups, religious organizations, universities, hospitals, and other private organizations. *See* Michael P. Vandenbergh, *Private Environmental Governance*, 99 Cornell L. Rev. 129 (2013).

9. *See* Sarah E. Light & Eric W. Orts, *Parallels in Public and Private Environmental Governance*, 5 Mich. J. Envtl. & Admin. L. 1 (2015).

10. Michael P. Vandenbergh & Jonathan M. Gilligan, *Beyond Gridlock*, 40 Colum. J. Envtl. L. 217 (2016); Paul C. Stern & Michael P. Vandenbergh, *Governance Beyond Governments: The Effort to Slow Climate Change*, *in* Oxford Handbook on International Environmental Governance (E. Brousseau et al. eds., forthcoming 2018).

actions, whether the actions are taken by governments or private organizations. Similarly, when we refer to "policymakers," we include both public policymakers (e.g., politicians and federal, state, and local agency managers) and private policymakers (e.g., the managers of climate or efficiency initiatives in corporations, advocacy groups, universities, and civic and cultural organizations).

The DDPP report seeks to describe the economic and policy implications of deep decarbonization "based on a detailed year-by-year analysis of the changes in U.S. physical infrastructure required to achieve deep decarbonization."[11] In other words, the report is designed to focus on changes in physical infrastructure or technology. Thus, behavior change is not an explicit aspect of the DDPP. It is not a part of any of the three DDPP "pillars," and none of the four DDPP pathways relies on explicit behavior change interventions to achieve emissions reductions. Nevertheless, behavior change remains central to the project: the demand for energy services and uptake and use of technologies that reduce carbon emissions, particularly in the domains of energy efficiency and renewable energy, require massive amounts of behavior change between now and 2050, mainly of types W, E, and R.

For example, the DDPP modeling includes electrification of the entire motor vehicle fleet, which requires a major shift in the vehicle purchasing and use behavior of individuals and organizations. We identify a number of areas in this Article in which behavior change is necessary to achieve the outcomes of the pathways, and we discuss the implications for laws, policies, and programs. We discuss programs as well as laws and policies because state-of-the-art behavior change initiatives often rely more on programs (e.g., the use by public and private organizations of informational interventions such as labeling and feedback to reduce household energy use) than on laws or policies.

The DDPP study carefully avoids any explicit assumptions about lifestyle change or behavior change of types A and D, which reduce energy services. This approach echoes President George H.W. Bush's famous 1992 statement at the first Earth Summit (the United Nations Conference on Environment and Development) in Rio de Janeiro that "the American way of life is not up for negotiation. Period."[12] The assumption may be that rapid technology uptake and use are possible, but conservation or curtailment behaviors and lifestyle changes are either less viable from a political or policy implementation perspective, are less malleable, or are less subject to modeling. We do not make such assumptions, and instead examine the potential of all the above types of behavior.

Although it is difficult to predict many energy behavior changes, a goal of the DDPP effort is to enable policymakers to anticipate "forks in the road" so they can avoid dead ends in the shifts in physical infrastructure necessary for the four modeled pathways.[13] Forks in the road exist for behavior change as well: beliefs and habits are hard to change, so policymakers would be smart to account for behavior early in the process of pursuing deep decarbonization. This is most obviously the case for behaviors that affect infrastructure development, such as consumer choices about whether to live near good public transportation or what size new home to purchase.

The behaviors we examine include both technology uptake and technology use, with the former involving the extent to which new technologies are adopted (e.g., consumer purchases of plug-in hybrid electric versus standard gasoline-fired motor vehicles), and the latter involving the extent to which adopted technologies are used or deployed in the way that will enable modeled emissions reductions to be achieved (for convenience, we call this "optimal use"—a very simple example is turning off lights in unoccupied rooms).[14] To identify the optimal behaviors to target, we argue that policymakers should not simply assess the technical potential of a proposed behavior change (the total emissions reductions that could be achieved if all behavior is changed), but also the plasticity of the behavior (the proportion of potential adoptions of particular target behaviors that is reasonably achievable) and the policy plasticity or initiative feasibility (the ability to adopt effective interventions to address that behavior).[15]

Similarly, although regulatory intervention to produce lifestyle change is certainly not likely to be viable in the near term and may not be a desirable role for government, major lifestyle changes that affect energy use and carbon emissions have occurred over the past four decades (e.g., suburbanization) and will certainly occur over the next four decades. Public and private policymaking will affect these lifestyle changes, and forks in the road will arise with regard to lifestyle changes just as they will with new physical infrastructure. It is true that lifestyle shifts are more difficult to subject to quantitative modeling than many other aspects of the energy system. Yet, policy decisions do affect lifestyle changes, these effects can be as important as the decisions that will affect the success of the four DDPP pathways, and it may be possible to anticipate these effects in a valuable way.

To that end, we provide initial thoughts about the types of lifestyle changes that may matter over the next four decades and the implications for deep decarboniza-

11. US 2050 Report, Volume 2, *supra* note 3, at 8.
12. Thalif Deen, *U.S. Lifestyle Is Not Up for Negotiation*, Inter Press Service, May 1, 2012, www.ipsnews.net/2012/05/us-lifestyle-is-not-up-for-negotiation/.
13. US 2050 Report, Volume 2, *supra* note 3, at 67, 73.
14. We use "optimal" in a broad sense to mean the use of the technology that yields the level of efficiency gains assumed by the DDPP modeling to result from the adoption of that technology.
15. *See* Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency (EPA), Opportunities to Reduce Greenhouse Gas Emissions Through Materials and Land Management Practices (2009) (EPA 530-R-09-017) [hereinafter Opportunities to Reduce Greenhouse Gas Emissions], *available at* https://www.epa.gov/sites/production/files/documents/ghg-land-materials-management.pdf (discussing "net technical potential"); Dietz et al., *supra* note 1 (discussing "behavioral plasticity"); Jonathan M. Gilligan & Michael P. Vandenbergh, *Accounting for Political Feasibility in Climate Instrument Choice*, 32 Va. Envtl. L.J. 1 (2014) (discussing "initiative feasibility"); Vandenbergh & Gilligan, *supra* note 10, at 251 (discussing "policy plasticity").

tion. We begin with a brief overview of the DDPP and the framing of carbon sources, then identify the behavior changes required for deep decarbonization, and wrap up by examining the range of laws, policies, and programs that could induce these types and levels of behavior change.

II. The Core Elements of the DDPP

According to the DDPP, to achieve its targeted 80% reduction in net carbon dioxide equivalent (CO_2e) below 1990 levels and annual per capita energy use of 1.7 metric tons of CO_2 by 2050, deep decarbonization in the United States will require an 8% annual decrease in emissions intensity per unit of economic activity and a 5.5% annual decrease in per capita emissions.[16] The DDPP identifies three "pillars" that must be in place for any technology pathway to reach these deep decarbonization goals: energy efficiency (e.g., acquisition and use of more-efficient light bulbs); decarbonization of electricity (e.g., adoption of renewable sources of electricity); and switching end use fuel to electric sources (e.g., acquisition and use of electric cars). Assuming that these pillars are in place, the DDPP models four distinct technology pathways to deep decarbonization: a high-renewables pathway (High Renewables); a high-carbon capture and storage pathway (High Carbon Capture and Storage (CCS)); a high-nuclear pathway (High Nuclear); and a mixed pathway (Mixed Scenario).

Deep decarbonization is achieved with existing and near-commercial technologies and does not require deployment of new technologies. Keys to successful transitions include timely replacement of infrastructure at the end of its lifetime with efficient and low-carbon alternatives, technological progress that enables price declines and widespread consumer adoption of existing low-carbon technologies, cross-sector coordination between energy supply and demand side sectors, and transformation of the business models used by network energy producers, distributors, and marketers. In the DDPP modeling, equipment users acquire more-efficient equipment in a timely fashion and use it in a way that achieves its efficiency potential—which we describe as optimal use.

The challenge of the DDPP is clear from a quick assessment of what the household emissions, measured on a per capita basis, must be in 2050 if deep decarbonization is to occur. The modeling for the DDPP initiative sets the U.S. population in 2050 at 440 million. As a result, the 80% reduction in net CO_2e below 1990 levels goal of the DDPP assumes that CO_2 levels will be 1.7 tons per capita in 2050, as compared to roughly 17 tons today.[17] This is an ambitious goal, and it is important to put this reduction in perspective. To achieve an 80% reduction in emissions by 2050, the average American in 2050 will need to emit roughly one-and-one-half to two times what the average Indian emits today.

This annual 2050 per capita total could be reached today with several round-trip flights between New York and California, or by driving a car of average fuel economy for a year, or heating and cooling the standard house for one year, or eating a standard American diet for one year, or purchasing the standard amount of consumer goods, and doing nothing else to emit carbon.[18] Although the DDPP envisions reducing the carbon intensity of several of these activities (e.g., by electrifying the motor vehicle fleet and decarbonizing the supply of electricity), achieving 1.7 tons per capita of CO_2 emissions in 2050 will not be easy.

The DDPP report achieves this level of decarbonization while assuming that the consumer use of energy goods and services in 2050 is very similar to today.[19] Through major efficiency gains, the DDPP modeling concludes that the demand for energy services can be maintained with current or higher levels of driving, home heating and cooling, lighting, and use of appliances.[20] In addition, the report concludes that the change in consumer costs for energy goods and services is likely to be small ($35 per month net increase in 2050 for a household).[21]

III. The Framing Challenge

We begin our analysis of the laws, policies, and programs necessary to achieve deep decarbonization by identifying how the framing of behavior in the DDPP report and other assessments of energy supply and demand affects perceptions about the role that behavior change can or must play in achieving deep decarbonization. We then turn to exploring in greater detail how behavior factors into the DDPP and how laws, policies, and programs could enable the DDPP to achieve its goal of 80% emissions reductions by 2050.

A. *Framing the Sources of Demand*

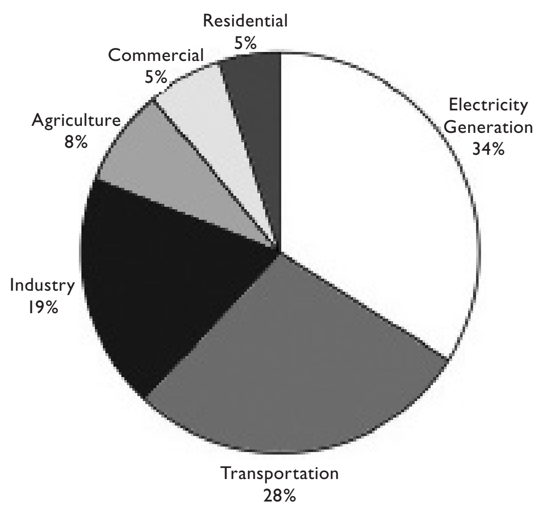
At the outset, the DDPP frames the principal sources of energy demand as the buildings, transport, and industrial sectors.[22] This is a common approach to framing the sources of energy demand, but it is important for this framing not to obscure the fact that many types of behav-

16. The DDPP report expresses the total 80% reduction goal in terms of CO_2e but the 1.7 tons of per capita emissions in terms of CO_2. The per capita total would be closer to two tons per capita if expressed in terms of CO_2e.
17. US 2050 Report, Volume 2, *supra* note 3, at 8.
18. *See* Vandenbergh & Gilligan, *supra* note 7. Examples of actions that emit in the range of four tons per year include international air travel, see International Civil Aviation Organization, *Carbon Emissions Calculator*, http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx (last visited Aug. 28, 2017); motor vehicle use of 12,000 miles at 27 miles per gallon (mpg), which equals 3.9 tons CO_2 assuming passenger car mpg of 27.5; home heating and cooling (U.S. Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) 2015 indicates that the average U.S. household emits 3.5 tons of CO_2 from heating and cooling); and the purchase of consumer goods over one year. For a discussion of the demands of decarbonization at a household level, see Nathan S. Lewis, *Powering the Planet*, 12 Engineering & Sci. 2, 12 (2007), *available at* https://ecee.colorado.edu/~ecen5555/SourceMaterial/NateLewis_Energy07.pdf.
19. US 2050 Report, *supra* note 3, at 24, 25.
20. *Id*. at 9, 24-25.
21. *Id*. at 28.
22. *Id*. at 6, 21, 25-34.

iors are involved in the technology uptake and use that affect the energy demand from the buildings, transport, and industrial sectors. Substantial amounts of individual and household behavior change can or must occur within those sectors, and a focus on behavior change can identify opportunities for additional, large, low-cost emissions reductions.

As we have noted in other work, a standard approach to source-framing, and one that is roughly parallel to the approach taken in the DDPP study, is the one represented by Figure 1.[23]

Figure 1. A Standard Approach to Source-Framing

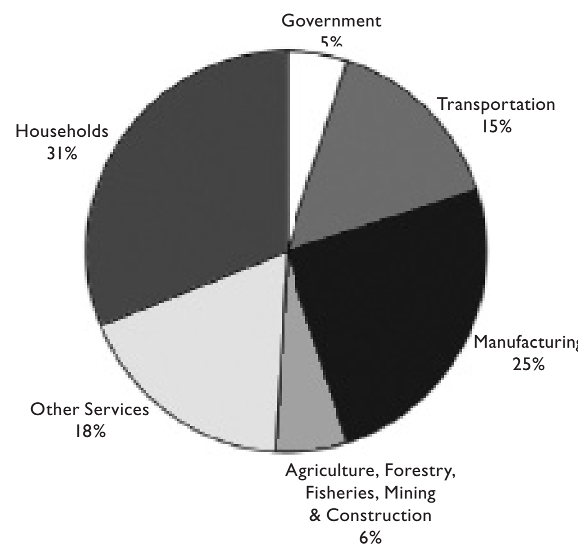


This configuration focuses policymakers' attention on the industry, electricity generation, and transportation sectors, much as the DDPP approach focuses on the buildings, transport, and industrial sectors. With the standard framing represented in Figure 1, the residential or household sector only contributes roughly 5% of the total, suggesting that household and individual behavior is not an important source of emissions. Similarly, if the sources are framed as the buildings, transport, and industrial sectors, the role of individuals and households can appear to be minimal.

This is only one way to frame the sources of CO_2 emissions, however, and the 5% share for households in Figure 1 is only accurate if the emissions associated with household electricity use are allocated to the electric power sector and the emissions associated with household motor vehicle use are allocated to the transportation sector. Whether the approach used is the one presented in Figure 1, the three-sector approach used by the DDPP, or others,[24] it is important for this framing not to divert attention from the many and significant contributions of individuals and households through multiple types of behavior, including the technology uptake and use that affect the carbon emissions from driving, household energy use, and the purchase of other goods and services. The key for this Article is to recognize the effects of framing and to ensure that framing does not lead policymakers who seek to achieve deep decarbonization to miss cost-effective, timely, and viable options.

What happens if the emissions associated with household energy use and driving are included in the household sector? As Figure 2 suggests, from this perspective, the household sector contributes roughly one-third of all U.S. emissions.[25] Including emissions from the production and distribution of consumer products would further increase the proportion.

Figure 2. Adjusted U.S. Household Sector Emissions



No one type of framing is best for all purposes, but the framing matters because the perceived size and type of sources of energy demand and carbon emissions can affect policymakers' perceptions not only about the optimal targets for climate policy, but also about the optimal types of interventions. For instance, if the source of electricity emissions is seen to be the utility sector, policies that shift the form of electricity generation (e.g., carbon pricing and regulation, renewable power standards) are the natural response. In contrast, if household demand for electricity is seen as an important source, the interventions may include more than those that shift non-household behavior, such as choices about the form of electricity generation in central

23. Michael P. Vandenbergh et al., *Implementing the Behavioral Wedge: Designing and Adopting Effective Carbon Emissions Reduction Programs*, 40 ELR 10547, figs. 1 & 2 (June 2010).
24. Another way to frame environmental issues is to distinguish between sectors and sources, as EPA has noted in the area of materials management. *See* Opportunities to Reduce Greenhouse Gas Emissions, *supra* note 15. This framing, in turn, can have important effects on the relative priority assigned to household behavior such as recycling in the selection of climate mitigation measures.
25. Definition of household sector is based on Michael P. Vandenbergh & Anne C. Steinemann, *The Carbon-Neutral Individual*, 82 N.Y.U. L. Rev. 1673 (2007). The chart is from Vandenbergh et al., *supra* note 23, and based on U.S. Department of Commerce, U.S. Carbon Dioxide Emissions and Intensities Over Time: A Detailed Accounting of Industries, Government, and Households 7, fig. 3 (2010).

power plants and the efficiency of the equipment available for purchase by households (e.g., water heaters). Instead, they also may include interventions to change household behavior directly, which may be more viable as policy options in many cases: interventions such as incentives and information to affect household purchases of energy-using equipment, widespread provision of monthly comparative electricity use data, provision of devices that provide immediate feedback regarding household energy use, and an option offered to households to shift electricity supply to a producer that generates power from renewable sources.

Over the long term, the framing of source categories also affects perceptions about the role that lifestyle shifts and other major social trends will play in reducing U.S. CO_2e emissions in 2050. If policymakers view households as an important source, they may be more likely to consider actions that affect choices about the location, size, type, and use of homes and motor vehicles when they reach forks in the road affecting these behaviors. The resulting policy responses may yield quicker, larger, or more cost-effective CO_2e reductions or may at least reduce the risk that social and behavioral trends will undermine the emissions reductions achieved by the types of approaches included in the DDPP report.

B. *Framing the Energy Terminology*

Definitional challenges also can obscure important aspects of household energy use and carbon emissions and undermine efforts to understand the role of behavior change in achieving deep decarbonization. As already mentioned, it is important for our purposes to distinguish between energy demand and energy service demand, between energy efficiency and energy conservation or curtailment, and between technology uptake and use.

The DDPP initiative follows the standard approach of defining energy services to be the physical benefits that energy use provides, whether the passenger-miles traveled, the amount of lighted and air-conditioned space, the loads of dishes washed, or ton-miles of freight moved. In contrast, energy demand is the energy used to supply those services. Energy efficiency involves reducing the energy used to provide an energy service, whereas conservation or curtailment involves actions that reduce the demand for the energy service.

We elaborate on the importance of the distinction between technology uptake and use with two examples, involving fuel-efficient water heaters and plug-in hybrid vehicles. On the first, a deep body of research demonstrates that individuals are subject to both cash-flow constraints and bounded rationality and that appliance installers are subject to similar constraints, as well as market failures.[26] The result is that the most cost-effective water heaters are often not sold, and when they are sold, the installers set the water temperature at a level that is well above recommended levels, reducing the efficiency gains that could be obtained from the more fuel-efficient water heaters.[27]

Similarly, plug-in hybrid vehicles typically yield the largest emissions reductions if the plug-in feature is used, essentially turning the vehicle into an electric vehicle as opposed to a hybrid gas-electric vehicle.[28] Use of the plug-in feature is also typically cheaper for the vehicle user than use of the gas-electric hybrid mode. Preliminary research appears to suggest, however, that although the uptake of plug-in hybrids has been robust, roughly 70% of consumers who purchase plug-in hybrids never use the plug-in feature.[29] Instead, for a variety of non-price-related reasons, including the hassle of plugging in the vehicle, they opt to rely on the vehicle as a gas-electric hybrid, not an electric vehicle. The result is that an accurate assessment of the carbon emissions reductions and economics of plug-in hybrid vehicles should account for the increased energy use, cost, and carbon emissions associated with the widespread failure to use this technology in an optimal way.

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26. *See* Paul C. Stern et al., *The Effectiveness of Incentives for Residential Energy Conservation*, 10 Evaluation Rev. 147 (1986); Stern et al., *supra* note 6; Gerald T. Gardner & Paul C. Stern, Environmental Problems and Human Behavior (2002).

27. *See*, *e.g.*, Sarah Goorskey et al., *Home Energy Briefs: #5 Water Heating*, 2 Rocky Mountain Inst. 1, 2-3 (2004), http://gfxtechnology.com/RMI-HE-5.pdf:

> Turn down the water temperature. If you have to mix hot and cold water to get the desired temperature, your water heater temperature is set too high and you're wasting energy and money. Many heaters are set to 140ºF or higher. For most households, 115-120ºF is sufficient. For each 10-degree reduction, you can save up to 5 percent on your water heating costs.

(citing EIA, A Look at Residential Energy Consumption in 2001 (2001); EIA, Water-Heating Consumption Tables (2001), *available at* https://www.eia.gov/consumption/residential/data/2001/pdf/2001ce_tables/waterheat_consump2001.pdf); Gerald T. Gardner & Paul C. Stern, *The Short List: The Most Effective Actions U.S. Households Can Take to Curb Climate Change*, 50 Env't: Sci. & Pol'y Sustainable Dev. 12, 19 (2008), *available at* http://www.tandfonline.com/doi/pdf/10.3200/ENVT.50.5.12-25 (noting that water heating accounted for 6.5% of "total U.S. individual/household energy consumed by end use" in 2005 and was the third-largest area of in-home consumption, and that turning down a water heater thermostat from 140ºF to 120ºF results in energy savings of 0.7%).

28. The advantages of an electric car depend on the carbon intensity of the grid, and electric cars are more carbon-intensive in the Upper Midwest, which has carbon-intensive electric power plants. *See* Matt Kotchen et al., *Spatial and Temporal Heterogeneity in Marginal Emissions: Implications for Electric Cars and Other Electricity-Shifting Policies*, 107 J. Econ. Behav. & Org. 248 (2014).

29. *See* David Roberts, *Wireless Charging: The Key to Unlocking an Electric Vehicle Revolution*, Vox, May 24, 2016, https://www.vox.com/2016/5/24/11677684/wireless-charging-electric-vehicles. This finding is from an unpublished private study, so it is not a basis for drawing firm conclusions about the behavior of plug-in hybrid drivers, but it is consistent with other, publicly available studies of recharging behavior. *See* Gil Tal et al., Institute of Transportation Studies, University of California, Davis, Charging Behavior Impacts on Electric Vehicle Miles Travel: Who Is Not Plugging In? (2013); Stephen Zoepf et al., Charging Choices and Fuel Displacement in a Large-Scale Plug-In Hybrid Electric Vehicle Demonstration (2015) (unpublished manuscript on file with authors). The finding is also consistent with a study involving recharging behaviors in Norway. Erik Figenbaum & Marika Kolbenstvedt, Institute of Transport Economics, Learning From Norwegian Battery Electric and Plug-In Hybrid Vehicle Users: Results From a Survey of Vehicle Owners (2016) (TOI report 1492/2016) (finding that 55% of the total kilometers driven by plug-in electric hybrids are in electric mode and 45% are in hybrid mode, and that 75% of Norwegian plug-in hybrid electric vehicle drivers never charge their hybrids at work even though recharging is available).

IV. The Role of Behavior in the DDPP

How can laws, policies, and programs that target behavior change be employed to facilitate decarbonization? As we have noted above, many types of behavior change must occur for each of the DDPP pathways to achieve deep decarbonization. To understand the laws, policies, and programs required to achieve deep decarbonization, it is important to drill more deeply to identify the specific types of behavior change required and the state of knowledge about effective interventions for these types of behaviors. We assume at the outset that the new technologies will be available at attractive prices because of market developments, carbon pricing measures, or equipment efficiency standards. Our focus is on the additional interventions that can or must be undertaken to supplement these other measures.

A. *Behavior in the DDPP Efficiency Assumptions*

The DDPP report includes substantial uptake of new technologies, and thus consumer behavior change, in its modeled efficiency gains and in the availability of new energy sources included in the modeling. Efficiency is a "pillar" of the deep decarbonization analysis, but the DDPP report does not include a "High Efficiency" pathway among its four pathways for achieving deep decarbonization. Instead, the DDPP report builds in large increases in efficiency for all of the pathways, enabling the report to include substantial economic growth and an increase in population to 440 million in the model while reducing "final energy" by 2050.

Although it is important to understand the source of these efficiency gains to understand what behavior change must occur to achieve deep decarbonization, this is no easy task. The DDPP modeling adopts the energy demand projections of the U.S. Department of Energy, Energy Information Administration's (EIA's) 2013 Annual Energy Outlook (AEO) through 2040 (the last year of the AEO projections), and draws on the AEO analysis to create projections through 2050.[30] The AEO analysis assesses projected demand for energy services and energy efficiency for the pre-2040 period, projecting that energy service demand will increase by 0.3% and that energy efficiency will increase each year, yielding a substantial energy demand increase in the base case used by the DDPP.[31] In addition, the DDPP modeling includes enhanced efficiencies. Thus, the starting point for the DDPP analysis, before the assumption of enhanced efficiencies, itself includes major annual efficiency gains.[32]

The reliance on the AEO raises two important questions. First, are the AEO estimates reasonable? Second, to what extent is behavior change included in or required by the AEO's annual energy-efficiency gains?[33] On the first question, recent research by Michael Wara and colleagues suggests that the National Energy Modeling System (NEMS) model that serves as the basis for the AEO analysis has consistently overprojected electricity sales for several decades.[34] In addition, NEMS overprojected energy-related CO_2 emissions in the United States from 1999 to 2015.[35] By the 10-year mark, the accumulation of annual positive projection errors resulted in total overestimation of emissions by a value equivalent to 20% of emissions in the base year, a meaningful degree of inaccuracy.

To the extent that the overprojections reflect an unanticipated transition of power production from coal to natural gas, or the Great Recession, they may be a time-limited phenomenon. But to the extent that the positive bias of the NEMS model has other causes, such as reduced energy demand,[36] it may be a promising development for the DDPP: if the measures included in the four pathways fall short of intended reductions, the shortfall may be cushioned somewhat by lower levels of energy demand than projected during the pre-2050 period. In addition, if the lower levels of energy demand are in part the result of greater than projected levels of energy behavior change, this bodes well for the behavioral aspects of the DDPP modeling.[37]

On the second question, widespread uptake and use of many types of more efficient equipment (weatherization (W) and efficiency (E) behaviors) are necessary to achieve the increased efficiency included in the AEO. Some of the

30. Note that the DDPP uses the 2013 AEO report, which only projects through 2040. The DDPP states that it extrapolates to 2050 for the inputs it uses from AEO. US 2050 Report, *supra* note 3, at 8.
31. EIA, Annual Energy Outlook 2013—With Projections to 2040, at 121 (2013) (DOE/EIA-0382(2013)) [hereinafter EIA AEO 2013].
32. EIA assumes efficiency improvements in the AEO reference case. The DDPP builds on the reference case by reapplying some of the same improvements (such as replacement of retired residential appliances with "substantially more efficient equipment," so some efficiency improvements will have been double-counted). EIA, Assumptions to the Annual Energy Outlook 2013, at 31 (2013) [hereinafter EIA Assumptions]. For the specific improvements the DDPP assumes, see US 2050 Report, *supra* note 3, at 13.
33. According to the AEO assumptions document, "one of the implicit assumptions in the Residential Demand Module is that, through 2040, there will be no radical changes in technology or consumer behavior." EIA Assumptions, *supra* note 32. In other words, no new efficiency regulations are assumed, but at the same efficiency level, future technologies are assumed to be less expensive than those available today. When choosing new or replacement technologies, consumers are assumed to behave similarly to how they behave today. *Id*.
34. *See* Michael Wara et al., *Peak Electricity and the Clean Power Plan*, 28 Electricity J. 18 (2015).
35. Michael Wara, *Instrument Choice, Carbon Emissions, and Information*, 4 Mich. J. Envtl. & Admin. L. 261, 280-81 (2015), stating that

> [c]alculation of forecast error for 152 year pairs of NEMS forecast and reported energy-related carbon dioxide emissions allows for an estimate of NEMS forecast error as a function of year relative to the year the forecast was made. . . . Over the time interval from 1999 to 2015, the forecasts made by NEMS exhibited a strong positive bias. The model has a strong tendency during the study period to overestimate future emissions. By three years post-forecast, the average error is 383 [million metric tons] MMT CO_2e or seven percent of 2012 emissions. By five years post-forecast, average error is 626 MMT CO_2e or twelve percent of 2012 emissions. By ten years, post-forecast, average error appears to stabilize for the time period evaluated at approximately 1100 MMT CO_2e or twenty percent of 2012 emissions.

36. Wara indicates that reductions in energy demand may be one of three reasons why the AEO overpredicted carbon emissions. *See id*. at 276.
37. *See* International Energy Agency, Tracking Clean Energy Progress 2014 (2014) (noting world economy carbon intensity in 2010 was roughly equal to in the mid-1990s and above 1999-2002).

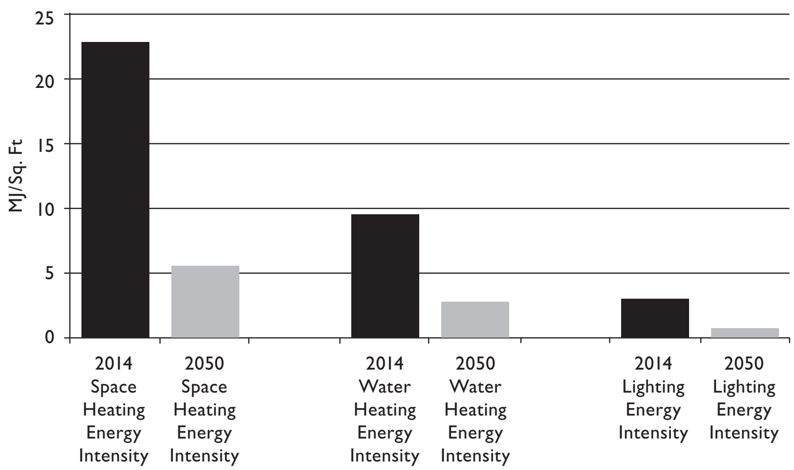
increased efficiency arises from shifts in the energy efficiency of motor vehicles and buildings.[38] As to increasing efficiency from household equipment, the AEO models energy use from systems for heating, ventilation, and air conditioning (HVAC), water heating, refrigeration, freezers, dishwashers, clothes washers and dryers, lighting, televisions, personal computers, and many others.[39]

On top of the AEO efficiency gains, the DDPP modeling includes additional efficiency gains. The modeling accomplishes this principally with stock rollover of equipment by subsector to higher-efficiency versions of current stocks.[40] For example, HVAC systems are replaced by more-efficient electric systems for existing buildings and are adopted for new buildings. This change, along with the decarbonization of the electric supply, allows buildings not only to be more efficient, but also to generate minimal carbon emissions from heating and cooling.

In addition, the DDPP modeling includes replacement of gas water heaters with heat pumps at the end of the gas water heaters' useful lives and replacement of incandescent and compact fluorescent lamp (CFL) light bulbs by light-emitting diodes (LEDs) at the end of their useful lives. This results in a great deal of energy efficiency (incremental to substantial improvements already in the AEO) in all of the DDPP deep decarbonization scenarios. The improvements in technology performance include everything from light bulb efficiency (watts per lumen) to the aerodynamic efficiency of vehicles; and these efficiency improvements, which all require behavior change associated with the uptake and optimal use of the more-efficient items, are essential to achieving the emissions target. Recent research suggests that some of these changes are already having a measurable effect on energy use: a study by Lucas Davis concludes that uptake of LED lighting explains the recent downturn in U.S. household electricity use.[41]

As discussed above, the electrification pillar is an important contribution to energy efficiency in the DDPP modeling, because in most important applications, the electric end-use technologies (electric vehicles, heat pumps) are more thermodynamically efficient than their combustion counterparts. For example, Figure 3[42] shows the improvement in the amount of energy required to deliver the same level of space and water heating, and lighting, per square foot of residential building, in 2014 and in 2050 under deep decarbonization. In all cases, the energy use is a factor of 3 to 5 below present levels, without reduction in energy services. This outcome results from replacing residential building equipment stocks on retirement with more-efficient technologies (e.g., LEDs in lighting, heat pumps in space and water heating).

Figure 3. Residential Energy Required in 2014 and in 2050 Under Deep Decarbonization



Importantly, the DDPP approach requires many steps before 2050. By 2030, the DDPP report calls for a high level of electricity decarbonization, with renewable and low-carbon energy sources totaling approximately 62% of mixed-case electricity generation, as compared with 27% in 2010.[43] This is accompanied by a high share of alternative (electric or fuel cell) light-duty vehicles (LDVs) in new vehicle sales; alternative LDV sales are anticipated to increase from a small share in the mid-2020s to a majority share of all LDV sales by 2030.[44] The report also includes, by 2050, high uptake of alternative heavy-duty vehicles (HDVs), building and industrial electrification, decarbonized pipeline gas, low-carbon biofuels, and large-scale flexible loads.

38. EIA AEO 2013, *supra* note 31, at 36.
39. For rollover of equipment in the AEO report, the assumption is that consumers will act the same as currently (i.e., no feel-good green purchases requiring behavior change), but that in most cases, efficiency will be greater for replacement appliances because for any given efficiency level, future prices of technology will be lower. This leads to overall efficiency gains without behavior change (assuming that purchasing more-efficient and cheaper equipment at the end of the useful life of existing equipment is not "behavior change"). As to the technologies included in the AEO, the EIA assumes a level of turnover for the following equipment: "space conditioning (heating and cooling), water heating, refrigeration, freezers, dishwashers, clothes washers, lighting, furnace fans, color televisions, personal computers, cooking, clothes drying, ceiling fans, coffee makers, spas, home security systems, microwave ovens, set-top boxes, home audio equipment, rechargeable electronics, dehumidifiers, external power supplies, and VCR/DVDs." *Id*. at 28. *See also* EIA Assumptions, *supra* note 32, and supporting data files from NEMS, various years, http://www.eia.gov/forecasts/aeo/assumptions/ (last visited Aug. 28, 2017).
40. The DDPP builds on the AEO model by more aggressively assuming that all (not just some) retired equipment is replaced by a more-efficient version on a timely basis at the end of its useful life. The DDPP identifies the additional efficiencies over and above those included in the AEO: "Highly efficient building shell required for all new buildings; new buildings require electric heat pump HVAC and water heating; existing buildings retrofitted to electric HVAC and water heating; near universal LED lighting in new and existing buildings." US 2050 Report, *supra* note 3, tbl. 6.
41. Lucas W. Davis, *Evidence of a Decline in Electricity Use by U.S. Households*, 37 Econ. Bull. 1098, 1102 (2017).
42. DDPP, Pathways to Deep Decarbonization in the United States, Legal Pathways Seminar slide 72 (May 10, 2016).
43. Calculated from data in the "electricity" graph under Mixed Scenario for the United States. *See* DDPP, *Visualization of Country Scenarios*, http://deepdecarbonization.org/countries/visualization-of-country-scenarios/ (last visited Aug. 28, 2017).
44. US 2050 Report, *supra* note 3, at 64, 73.

What specific types of change in consumer behavior are necessary to achieve the modeled emissions reductions? Such behavior changes are most important regarding decisions that affect the energy use attributed to transportation and buildings and less important for the industry and electricity generation sectors. The uptake rates in the DDPP modeling require consumers to choose low-carbon options when getting new equipment to replace current equipment at the end of its natural life cycle, and to do so on a timely basis for a wide range of consumer goods,[45] including items such as LDVs,[46] light bulbs,[47] and residential water heaters.[48] The DDPP modeling results also require that this timely uptake of more-efficient technologies will persist throughout the pre-2050 period (and presumably beyond, since emissions must decline after 2050 to achieve the 2°C goal) and that these technologies will be used in ways that achieve the modeled energy use reductions.

For this to occur, retailers will need to make more-efficient goods available and consumers will need to pay up-front capital costs to be offset by savings in fuel purchases for such products and services as alternative fuel vehicles, renewable electricity generation, and electric heat pumps for space and water heating.[49] Consumers also will need to be willing to pay roughly $35 per month more on energy goods and services for electricity and equipment costs minus savings from fuel.[50] In other words, consumers (or landlords in rental buildings) will invest in higher up-front costs to be offset by lower fuel costs.[51] Although not discussed explicitly, the modeling results also require the optimal use of the new, more-efficient equipment, allowing the equipment to deliver the modeled levels of efficiency. Consumers thus will need to have adequate information, plus the resources, skills, and motivation to use the equipment as intended.

Because the DDPP report includes aggressive efficiency gains in all cases, the modeling results require that policymakers take whatever steps needed to drive the necessary efficiency. This will necessitate major policy choices to promote the levels and types of technology uptake and use necessary to achieve high levels of efficiency. As the fuel-efficient water heater and plug-in hybrid examples demonstrate, however, uptake of new, more-efficient technologies often does not occur in a timely fashion when old equipment is at the end of its useful life and new equipment is available that would be cheaper over its expected life cycle (described as "timely replacement" in the DDPP report).[52]

Many barriers can delay uptake of new technologies even if the current equipment is at the end of its useful life and the new, more-efficient equipment is cheaper than alternatives. In some cases, consumers do not act simply based on price incentives. In others, intermediaries do not have incentives to promote efficiency at the individual or household level. In these situations, laws, policies, and programs may be necessary to achieve the modeled level of technology uptake. In addition, new technologies are often not used in optimal ways. Again, laws, policies, and programs may be necessary to ensure that equipment is used in the most efficient way.[53]

B. *Behavior in the Four DDPP Pathways*

In addition to the uptake and use of more-efficient technologies included in the core DDPP modeling, behavior is an important factor in each of the four specific DDPP pathways (High Renewables, High Nuclear, High CCS, and the Mixed Scenario). Each of these pathways depends for its effectiveness on behavior that supports major social transitions from fossil fuels to other sources of energy. For example, in the High Renewables Scenario, in rough terms, the following occurs: as to liquid fuels, petroleum is displaced by electricity, with small amounts of renewable fuels; as to gas fuels, standard natural gas is replaced by biogas and synthetic natural gas; for electricity, wind, solar, and hydropower displace fossil fuels, with an ongoing role for nuclear power. Similar transitions occur in each of the other three cases.

As the High Renewables example suggests, more is involved than the changes in consumer behavior discussed above with reference to achieving efficiency gains. Social acceptance of and public and institutional support for transitions from fossil fuel to other sources of energy and the other transitions necessary for each pathway will be critical behavioral issues. They include not only the uptake and use of the new technologies necessary to enable the transition, but also support for policies and shifts in employment, infrastructure, services, market organization, and other factors. In the High Nuclear Scenario, support will be needed for the siting, permitting, and operation of new nuclear plants and the transport and storage of the resulting waste.[54]

Similar issues can be expected to arise for the High CCS Scenario, although there is not yet much of a track record for anticipating the kinds of acceptance issues that will arise. CCS requires infrastructure at the capture,

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45. US 2050 Report, Volume 2, *supra* note 3, at 10, 12, 49, 63.
46. *Id*. at 22, 41, 58, 63, 68, 73, 89.
47. *Id*. at 63.
48. *Id*. at 50, 51, 63.
49. *Id*. at 26, 27.
50. *Id*. at 28.
51. *Id*. at 41.
52. The DDPP modeling requires "timely replacement" with efficient equipment at the end of the useful life of the inefficient equipment. *Id*. at 10, 52, 54.
53. In the absence of highly effective initiatives focused on behavior change, analyses that assume that consumers and businesses will promptly replace existing equipment at the end of its useful life with the most efficient alternative, and will use the new technology in the most efficient way, will overpredict the contributions of the resulting efficiency gains to deep decarbonization.
54. In the absence of shifts toward acceptance of nuclear power, prompt substitution of nuclear power for fossil fuels is unlikely; a 2015 Gallup poll found U.S. support for nuclear power to be only 51%—lower than it has been in more than a decade. Opposition to nuclear power was measured at 43%, suggesting that proposals to expand nuclear energy not only would be unlikely to garner widespread public support, but also would potentially be met with substantial resistance. *See* Rebecca Riffkin, *U.S. Support for Nuclear Energy at 51%*, Gallup, Mar. 30, 2015, http://www.gallup.com/poll/182180/support-nuclear-energy.aspx.

transportation, and storage stages, and the installation and operation of this infrastructure can raise public acceptance issues.[55] Initial reports and studies in the United States reveal either public ambivalence[56] or public fear[57] associated with CCS technology, both of which could affect policy efforts to invest in CCS infrastructure.[58]

Similarly, the adoption of autonomous vehicles could have dramatic implications for the net cost of deep decarbonization of the transportation sector if it results in very high asset utilization rates, but this might imply very different ownership models for private transportation. These types of sociotechnical transitions are beyond the scope of this Article, but we note that an extensive literature has examined these types of issues, with a particular focus on the requirements for successful transitions to more sustainable sociotechnical systems.[59] This literature should be valuable for the design of laws, policies, and programs regarding the sociotechnical transitions necessary for each pathway and for work on the types of lifestyle issues we discuss below.

V. Laws, Policies, and Programs to Promote Behavior Change

The measures that can promote the individual and household energy use behavior changes that will be necessary to achieve deep decarbonization are numerous and varied. In this Article, we identify several illustrative examples and a way to think about other possibilities. These individual and household behaviors are particularly critical for achieving the goals of the High Renewables Scenario and of the DDPP "efficiency pillar" that underlie all four pathways. The best established types of individual and household behavior change for achieving carbon reductions from efficiency and renewable energy involve household technology uptake and use in these categories[60]: (1) household equipment (HVAC systems, water heaters, other appliances, light bulbs, and other consumer equipment); (2) buildings (more-efficient new residential buildings and weatherization of existing buildings); and (3) motor vehicles (more-efficient and electric vehicles). In this discussion, we explore the laws, policies, and programs that can achieve the behavior change required by the DDPP modeling in these categories.

A. *The Plausibility of Behavior Change Initiatives for Climate Mitigation*

In our view, the literature on energy behavior change suggests that the achievements required for deep decarbonization are possible. Based on an analysis that focused on 2020 as the target date, we have argued that the potential for reduced carbon emissions from the uptake and use of more-efficient technology is substantial.[61] We have outlined an approach that could lead to a 20% reduction in emissions from the household sector, including household equipment, buildings, and motor vehicles, in the decade ending in 2020, through a combination of new technology uptake, more-efficient use of existing equipment, and curtailment or conservation. Although the DDPP report focuses on 80% emissions reductions by 2050, near-term emissions reductions are included in the DDPP modeling. For our analysis, we examined not only the technical potential of 17 action types, but also what we call the behavioral plasticity—the proportion of potential adoptions of particular target behaviors that is reasonably achievable—based on an assessment of the state-of-the-art programs available for these actions.

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55. Department of Energy and Climate Change, Developing Carbon Capture and Storage (CCS) Infrastructure: Consultation on Implementing the Third Party Access Provisions of the CCS Directive and Call for Evidence on Long Term Development of CCS Infrastructure (2010) (URN: 10D/989), *available at* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/42609/1008-cons-ccs-third-party.pdf; R. Stuart Haszeldine, *Carbon Capture and Storage: How Green Can Black Be?*, 325 Science 1647, 1647-48 (2009).

56. Paul W. Parfomak, Congressional Research Service, Summary, Community Acceptance of Carbon Capture and Sequestration Infrastructure: Siting Challenges (2008).

57. *See, e.g.*, Gregory Singleton et al., *Public Risk Perspectives on the Geologic Storage of Carbon Dioxide*, 3 Int'l J. Greenhouse Gas Control 100 (2009), *available at* https://sequestration.mit.edu/pdf/IJGGC_Singelton_Herzog_Ansolabehere.pdf.

58. Parfomak, *supra* note 56:

> At the policy level, this ambivalence may cause concern among legislators seeking to promote carbon control strategies that could impose significant costs on local communities or the U.S. economy overall. At the project level, this ambivalence may become outright opposition as community residents incorporate local considerations in their evaluation of a proposed CCS development.

This public mentality stems in part from a lack of familiarity with CCS technology. David E. Adelman & Ian J. Duncan, *The Limits of Liability in Promoting Safe Geologic Sequestration of CO_2*, 22 Duke Envtl. L. & Pol'y F. 1, 1, 3, 7 (2011) (citing Filip Johnsson et al., *Stakeholder Attitudes on Carbon Capture and Storage—An International Comparison*, 4 Int'l J. Greenhouse Gas Control 410 (2010); Jennie C. Stephens et al., *Learning About Carbon Capture and Storage: Changing Stakeholder Perceptions With Expert Information*, 1 Energy Procedia 4655 (2009); EIA, Annual Energy Outlook 2011—With Projections to 2035, at 42 (2011) (DOE/EIA-0383(2011)), *available at* http://www.pseudology.org/gazprom/EnergyOutlook2011.pdf; Curtis M. Oldenburg et al., *Certification Framework Based on Effective Trapping for Geological Carbon Sequestration*, 3 Int'l J. Greenhouse Gas Control 444, 444-45 (2009); Jean-Philippe Nicot, *Evaluation of Large-Scale CO_2 Storage on Fresh-Water Sections of Aquifers: An Example From the Texas Gulf Coast Basin*, 2 Int'l J. Greenhouse Gas Control 582, 582-83 (2008)). Some worry that it is unpredictable and dangerous; *see, e.g.*, Karsten Pruess, *On CO_2 Fluid Flow and Heat Transfer Behavior in the Subsurface, Following Leakage From a Geological Storage Reservoir*, 54 Envtl. Geology 1677, 1684 (2008). Gregory Singleton et al. concluded that "the risks of geological storage are likely to eventually be considered no worse than existing fossil fuel energy technologies." Singleton et al., *supra* note 57, at 1.

59. For an overview of prevailing theory concerning sociotechnical transitions, such as those from high-carbon to low-carbon energy systems, see Frank W. Geels & Johan Schot, *Typology of Sociotechnical Transition Pathways*, 36 Res. Pol'y 399, 399-417 (2007). For a more recent discussion focused on energy transitions, see Johan Schot et al., *The Roles of Users in Shaping Transitions to New Energy Systems*, 1 Nature Energy (2016).

60. The DDPP initiative focuses on new technology adoption, which many social science researchers believe is the most promising area for energy-related behavior change, since (assuming optimal use of the new technology) it only requires one action—purchase of the new technology—not multiple daily actions or a change in habits. Gardner & Stern, *supra* note 26; Dietz et al., *supra* note 1.

61. Dietz et al., *supra* note 1.

Table 1

Behavior Change	Behavior Category	Potential Emissions Reduction (MTC)	Behavioral Plasticity	RAER (MTC)	RAER (%I/H)
Weatherization	W	25.2	90%	21.2	3.39%
HVAC equipment	W	12.2	80%	10.7	1.72%
Low-flow showerheads	E	1.4	80%	1.1	0.18%
Efficient water heaters	E	6.7	80%	5.4	0.86%
Appliances	E	14.7	80%	11.7	1.87%
Low-rolling resistance tires	E	7.4	80%	6.5	1.05%
Fuel-efficient vehicles	E	56.3	50%	31.4	5.02%
Change HVAC air filters	M	8.7	30%	3.7	0.59%
Tune up AC	M	3.0	30%	1.4	0.22%
Routine auto maintenance	M	8.6	30%	4.1	0.66%
Laundry temperature	A	0.5	35%	0.2	0.04%
Water heater temperature	A	2.9	35%	1.0	0.17%
Standby electricity	D	9.2	35%	3.2	0.52%
Thermostat setbacks	D	10.1	35%	4.5	0.71%
Line drying	D	6.0	35%	2.2	0.35%
Driving behavior	D	24.1	25%	7.7	1.23%
Carpooling & trip chaining	D	36.1	15%	6.4	1.02%
Totals		233		123	20%

Based on the technical potential and behavioral plasticity of each behavior, we calculated the reasonably achievable emissions reduction (RAER) for each type of behavior change, which is the potential emissions reduction if the action is fully adopted by those who can adopt it multiplied by the behavioral plasticity of the action (we provided support for the calculations in supplemental online materials).[62] RAER, in Table 1, can be estimated in millions of tons of carbon (MTC) equivalent not emitted or as a percentage of all emissions from the individual/household sector (%I/H).

As the table suggests, many of these actions correspond to the technology adoption and optimal use (e.g., efficient water heater purchases and water temperature settings) that must occur for the DDPP efficiency assumptions to be realized, but our analysis also includes behavior change related to achieving more-efficient use of existing technology (e.g., changing the filters on an existing furnace) and conservation or curtailment (e.g., reducing the furnace thermostat setting in the winter). The bulk of the potential emissions reductions derives from technology adoption (the weatherization (W) and efficiency (E) behavior categories). We note that this is a conservative estimate of the potential savings from consumer behaviors, as some actions with high technical potential, such as the adoption of residential LED lighting, photovoltaic energy systems, and hybrid and electric vehicles, were not sufficiently widespread when this analysis was done to allow for justifiable estimates of plasticity.

62. Support for the calculations can be found in supplemental online materials to Dietz et al., *supra* note 1, *at* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2767367/bin/supp_106_44_18452__index.html.

B. *Specific Laws, Policies, and Programs to Achieve Deep Decarbonization*

What laws, policies, and programs could achieve the types of behavior change anticipated by the DDPP? The most viable options are too numerous and varied to present a comprehensive list here, but we provide an overview of the characteristics or principles associated with successful programs and multiple illustrative examples. As discussed above, behavior change must occur in at least the areas of optimal technology adoption and use of household equipment, buildings, and motor vehicles. Effective interventions will not only target consumers and other end-users directly, but also the individuals and organizations that can enhance or undermine consumer behavior change, including utilities, motor vehicle and appliance manufacturers, builders, home repair contractors, landlords, and retailers.

In each of the three areas (equipment, buildings, and motor vehicles), we focus on initiatives directed at those who are in a position to promote or discourage uptake and optimal use of efficient technologies (e.g., auto manufacturers, utilities, and landlords) and then turn to the ultimate consumers and users. As noted above, we include programs as well as laws and policies because many of the most successful behavior change interventions involve provision of information and other actions that are not comfortably categorized as laws or policies. For the same reason, we include not only interventions by government actors, but also by private governance initiatives in which the lead actor is a private organization (e.g., corporation, advocacy group, civic group, or religious organization).

C. Design Principles for Changing Behavior

Our starting point is that there is no simple playbook for behavior change. The fundamental lesson of several decades of research on energy and environmental behavior is that laws, policies, and programs are unlikely to succeed unless they are carefully tailored to the particular target audience and behavior. In addition, a growing literature has identified the following characteristics or design principles associated with effective laws, policies, and programs for energy and environmental behavior change.[63] First, although it is easy to be distracted by actions that are the most obvious (turning off lights), high-impact actions should be prioritized. These actions are marked not only by their large technical potential, but also high behavioral plasticity.[64] Furthermore, both technology adoption and use are important,[65] although much of the social and behavioral literature has focused on the latter.[66]

Second, laws and policies that combine financial and social incentives with well-presented and easily accessible information from trusted sources at points of decision are often most effective in achieving substantial carbon emissions reductions. Financial cost can play an important role in decisionmaking processes, but its role can be overstated as compared to other factors. Lowering prices can be an especially effective tool when dealing with one-time transfers to products that have large up-front financial costs.[67] However, financial incentives can fail to achieve optimal effects if implemented in ways that do not apply other design principles.

Third, nonpecuniary influences on behavior can provide opportunities to shift behavior at low cost. For instance, in some cases, appealing to social norms can be effective for changes aimed at sustained behavioral switches. Research has shown that providing information about common behaviors within a population can motivate individuals to model that behavior, reflecting how societal influence can affect personal actions.[68] People often modify their behavior in response to information that points out inconsistencies between their personal beliefs and day-to-day actions.[69] This desire for harmony between beliefs and actions can be addressed effectively with personalized information campaigns. Marketing energy programs through community groups and informal social networks has also proven highly effective.

Fourth, the way information is presented is also of crucial importance. What is particularly important for technology adoption choices is that relevant information be presented from trusted sources at points of decision. Research has shown that previous experiences or ideological worldviews can inherently color any decision, and therefore presenting information in a non-polarizing manner is best for influencing a wide audience base.[70] For narrower audiences, the proper information source is important. Additionally, presenting equivalent information in terms of avoiding losses as opposed to achieving gains can increase effectiveness.[71] Besides these framing techniques, keeping information simple and easily acted upon at important decisionmaking junctures is also important. Although individuals may hold strong feelings about certain issues, they may act in ways contrary to their beliefs if, at the time of their decisions, it is more convenient for them to do so.[72]

Fifth, cognitive costs matter in decisionmaking. As we mentioned above, habits are difficult to break. Individuals may choose a default option because its familiarity and convenience make more difference than a moral or financial

63. *See* Amanda R. Carrico et al., *Energy and Climate Change: Key Lessons for Implementing the Behavioral Wedge*, 2 J. Energy & Envtl. L. 61 (2011); Paul C. Stern et al., *Design Principles for Carbon Emissions Reduction Programs*, 44 Envtl. Sci. & Tech. 4847, 4847-48 (2010); Stern et al., *supra* note 6; Wolske & Stern, *supra* note 4.

64. Vandenbergh et al., *supra* note 23, at 4.

65. Amanda Carrico et al. suggest targeting product purchase decisions to promote efficient options and adoption of policies that promote efficiency and curtailment of product use. Carrico et al., *supra* note 63. *See also* Richard Osbaldiston & John P. Schott, *Environmental Sustainability and Behavioral Science: Meta-Analysis of Proenvironmental Behavior Experiments*, 44 Env't & Behav. 257 (2011) (recommending: determine which behavior is targeted before choosing the appropriate intervention for that behavior; and identifying types of intervention: making an option easy, providing prompts, providing justifications, providing instructions, giving rewards, performing social modeling, utilizing cognitive dissonance, providing feedback, making a commitment, and setting goals). Richard Osbaldiston and John Schott note that combinations of these interventions can be more successful than a single intervention, and they identify as the most promising combinations: rewards and goals, instructions and goals, commitment and goals, prompts and making it easy, prompts and justifications, and dissonance and justifications. As to best single interventions, they identify the following: cognitive dissonance, setting goals, using prompts, and using social modeling. They also recommend accounting for whether the goal is short- versus long-term behavior change (e.g., giving rewards is more effective for a one-time transfer than a sustained behavior change). *Id*.

66. *See* Ingo Kastner & Paul C. Stern, *Examining the Decision-Making Processes Behind Household Energy Investments: A Review*, 10 Energy Res. & Soc. Sci. 72 (2015). Ingo Kastner and Paul Stern note that decisions are made through bounded rationality: decisionmaking is based on aspects consumers find most relevant, with factors that include attitude (associated with expected consequence of the behavior), subjective norms (perceived social pressure to perform the behavior), perceived behavioral control (the estimated ability to perform the behavior), and ability. They note that energy consumption and recycling decisions are affected by these factors but that it is less clear whether these factors affect energy-related investment decisions. *Id*.

67. Vandenbergh et al., *supra* note 23, at 6.

68. *See* P. Wesley Schultz, *Changing Behavior With Normative Feedback Interventions: A Field Experiment on Curbside Recycling*, 21 Basic & Applied Soc. Psychol. 25, 36 (1998); Noah J. Goldstein et al., *A Room With a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels*, 35 J. Consumer Res. 472 (2008); P. Wesley Schultz et al., *The Constructive, Destructive, and Reconstructive Power of Social Norms*, 18 Psychol. Sci. 429 (2007).

69. Campbell K. Aitken et al., *Residential Water-Use—Predicting and Reducing Consumption*, 24 J. Applied Soc. Psychol. 136, 156 (1994); Steven J. Kantola et al., *Cognitive Dissonance and Energy Conservation*, 69 J. Applied Soc. Psychol. 416, 420 (1984); Chris A. Dickerson et al., *Using Cognitive Dissonance to Encourage Water Conservation*, 22 J. Applied Soc. Psychol. 841, 848 (1992).

70. Carrico et al., *supra* note 63, at 9.

71. *See* Suzanne Yates, Using Prospect Theory to Create Persuasive Communications About Solar Water Heaters and Insulation (1982 unpublished Ph.D. dissertation on file with authors). *See also* Paul C. Stern, *What Psychology Knows About Energy Conservation*, 47 Am. Psychol. 1227, 1227-28 (1992).

72. Gregory A. Guagnano et al., *Influences on Attitude-Behavior Relationships: A Natural Experiment With Curbside Recycling*, 27 Env't & Behav. 699, 713 (1995) (noting that the impact of attitudes on behavior are bounded by contextual factors that may reduce their applicability).

calculus.[73] Moreover, decisionmaking is limited by people's ability to process information. Well-designed labels or educated salespersons can counteract these decisionmaking shortcomings by providing relevant information conveniently at the point of decision.[74] Effective presentation can have oversized effects on decisionmaking.

Sixth, with unfamiliar technologies, quality assurance (e.g., through performance or financial savings guarantees) can be critical to inducing consumers to take the plunge when they may see the benefits as unproven. This appears to be important to increases in adoption of residential photovoltaic systems in both Germany and the United States.[75]

These characteristics or principles can be seen in the most successful programs that address the three areas of behavior change included in the DDPP modeling (household equipment, building efficiency, and motor vehicle efficiency), which we discuss in more detail below. For each of these areas, we first examine technology adoption and then turn to the use of the technology.

D. Household Equipment

In theory, at the end of the useful life of existing equipment, if efficient equipment is available at lower cost to a retail consumer than less-efficient equipment, the consumer will purchase the new, more-efficient equipment and will do so in a timely manner. This assumption is included in the AEO report, whose energy demand projections are adopted by the DDPP[76] and in the efficiency enhancements included in the DDPP report. Experience and empirical research demonstrate, however, that such timely replacement does not uniformly occur.[77] As Table 1 indicates, even the most effective interventions achieve plasticity of only 90%.

A number of barriers may discourage the timely uptake of more-efficient technologies. The retailers of equipment may have incentives not to advertise the most energy-efficient equipment, and the installers of equipment may have limited information about efficiency or may have incentives not to sell the most efficient equipment. In addition, in rental housing, the landlord is responsible for major equipment purchases, while the household pays the energy bills. This split incentive situation undermines uptake of even cost-effective new equipment. Similarly, homeowners may not purchase efficient equipment if they expect to sell the home before recouping the investment and do not believe that potential homebuyers will pay an adequate amount for the increased efficiency of the home. In addition, consumers may be affected by cognitive biases, limited information, or social norms that delay or prevent uptake of more-efficient equipment.

A government carbon price would create pecuniary incentives for household equipment uptake and optimal use and would serve as a floor for other initiatives. A carbon price alone is unlikely to be sufficient to rapidly accelerate technology uptake, however, so long as intermediaries lack incentives to sell lower carbon goods, or consumers lack information, or have strong countervailing influences, such as can occur if economic incentives undermine personal or social norms. Government requirements for utilities to achieve prescribed levels of efficiency could induce them to offer state-of-the-art informational programs (the descriptive norm-based Opower programs are an example).[78] However, unless the requirements are coupled with incentives for utilities to profit from reduced electricity sales, utilities are unlikely to pursue steps that would achieve optimal penetration of efficient technology.[79]

1. Technology Uptake

Laws, policies, and programs are often necessary to motivate retailers, installers, and landlords to promote the rapid uptake of more-efficient equipment. Examples include:

- *Retailers*. Mandatory government labeling of particularly efficient products occurs in some countries, but in the United States, the voluntary "Energy Star" program is the dominant approach to disclosure of the energy use of equipment.[80] Initially established by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE), Energy Star partners with private- and public-sector organizations to certify and label products, equipment, and appliances that are the most energy-efficient in their respective classes. In addition to providing information and guidance to consumers, Energy Star stimulates consumers to purchase and retailers to stock more-efficient equipment.

  Private standards and programs also exist to promote the sale of more-efficient equipment.[81] For example, a number of private initiatives by nongov-

73. *See* Cass R. Sunstein & Richard H. Thaler, *Libertarian Paternalism Is Not an Oxymoron*, 70 U. Chi. L. Rev. 1159 (2003). For an example of the effect of the status quo bias on rates of organ donation, see also Eric J. Johnson & Daniel Goldstein, *Do Defaults Save Lives?*, 302 Science 1338, 1338-39 (2003). *But see* Jon Jachimowicz et al., When and Why Defaults Influence Decisions: A Meta-Analysis of Default Effects (working paper), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2727301 (people may choose to opt out even if they intrinsically agree with the suggested choice due to perceived reduction of control, unsolicited advice, or implicit recommendation).
74. Carrico et al., *supra* note 63, at 7.
75. Paul C. Stern et al., *Household Production of Photovoltaic Energy: Issues in Economic Behavior*, *in* The Cambridge Handbook of Psychology and Economic Behaviour (Alan Lewis ed., 2d ed. Cambridge forthcoming 2018).
76. EIA Assumptions, *supra* note 32.
77. *See* Kastner & Stern, *supra* note 66, at 74; Susan Clayton et al., *Psychological Research and Global Climate Change*, 5 Nature Climate Change 640, 641-42 (2015).
78. For a discussion, see Vandenbergh & Gilligan, *supra* note 7. *See also* Ed Carroll et al., *Residual Energy Use Behavior Change Pilot*, Opower, Apr. 20, 2009.
79. *See* Michael P. Vandenbergh & Jim Rossi, *Good for You, Bad for Us: The Financial Disincentive for Net Demand Reduction*, 65 Vand. L. Rev. 1527, 1527-64 (2012).
80. The Energy Policy and Conservation Act of 1975 and the National Energy Conservation Policy Act of 1978 address comparative labeling on appliances.
81. *See* Vandenbergh & Gilligan, *supra* note 10, at pt. IV.B.

ernmental organizations and retailers promote the sale of more-efficient equipment. Working with the Environmental Defense Fund (EDF), Walmart has announced a range of initiatives that will reduce the carbon emissions associated with its retail products.[82] In an effort conducted with EDF, it has reduced the supply chain emissions associated with its products by more than 20 million metric tons, for example, and it recently collaborated with EDF, the World Wildlife Fund, and the Rocky Mountain Institute to announce a billion-ton reduction target in supply chain emissions by 2030.[83] It also has promoted efficient light bulbs and has published an online consumer guide to energy-efficient light bulbs, which compares the various attributes of halogen, CFL, and LED light bulbs to allow consumers to make informed purchasing decisions.[84]

- *Installers*. For equipment such as water heaters and HVAC systems, the firm that sells and installs this equipment is a critical player in the process of efficient technology uptake. A common observation is that customers often buy whatever equipment is on the back of the truck of the installers at the time they arrive to replace the equipment. In many cases, installers may not have a higher profit margin on efficient equipment, or if they do, they may not have the information on payback periods or incentives necessary to induce consumers to buy the equipment in large volumes, making the installer wary about carrying a large inventory of efficient equipment and promoting it to consumers.

  Although some utilities have targeted this area, the installer sector has been subject to only limited public and private governance efforts so far. Rapid uptake of more-efficient equipment may require new initiatives in this area, including public or private programs that motivate installers to sell efficient equipment and to provide them with state-of-the-art information that explains the advantages of efficient equipment to customers.[85] For example, programs designed to motivate lenders to provide financing for the installation of more-efficient equipment have been developed in recent years and may need to be expanded.[86]

- *Landlords and short-term homeowners*. Since the occupants of a home typically bear the energy costs associated with daily activities in the residence, landlords often will not gain the financial benefits of investments in energy-efficient appliances for rental properties and residential leases. Likewise, short-term homeowners who do not intend to live in a residence long enough to take full advantage of lower energy costs over the lifetime of an installed appliance will have little willingness to face the greater up-front costs associated with efficiency upgrades. These impediments to the purchase and installation of efficient household equipment are known as split incentives, and extensive research has documented the existence of split incentives as a common form of market failure.[87] For example, the International Energy Agency (IEA) found that 33% of U.S. rental households suffer from split incentive problems for refrigerators, 78% for water heaters, 53% for main space heating, and 5% for lighting.[88]

  Public and private governance responses are possible. For instance, municipalities and private organizations have responded to landlord-tenant split incentives with green leasing programs, which motivate landlords to install efficient equipment by enabling them to recoup some of the savings from efficiency investments.[89] Although green leases have become more common for commercial properties, they have struggled to find a foothold in the residential sector. Recent efforts to encourage them suggest room for progress. For instance, the San Francisco Bay Area Planning and Urban Research Association (SPUR) has conducted extensive research into how the city might implement a residential green lease program and has estimated that by amending the Rent Control Ordinance in San Francisco, the city could save 200 tons of carbon emissions annually at a cost of $39 per ton of emissions savings.[90] A greater emphasis on promotion of green leases by advocacy organizations, businesses, and municipalities could reduce the split incentive problem and increase the uptake and use of more-efficient household equipment.

82. Stephanie Clifford, *Unexpected Ally Helps Wal-Mart Cut Waste*, N.Y. Times, Apr. 13, 2012, http://www.nytimes.com/2012/04/14/business/wal-mart-and-environmental-fund-team-up-to-cut-waste.html.
83. *See* Vandenbergh & Gilligan, *supra* note 10, at 270; Vandenbergh & Gilligan, *supra* note 7, at ch. 5.
84. Walmart, *Choosing the Right Energy-Efficient Light Bulb*, https://www.walmart.com/ideas/diying/choosing-the-right-energy-efficient-light-bulb/48236 (last visited Aug. 28, 2017).
85. *See* Vandenbergh & Gilligan, *supra* note 7, at ch. 5. *See also* Scott Murtishaw & Jayant Sathaye, Lawrence Berkeley National Laboratory, Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use tbl. ES-2 (2006), *available at* http://escholarship.org/uc/item/6f14t11t.
86. For example, the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, has released best practice guidelines for residential property-assessed clean energy (PACE) programs, which allow homeowners to borrow for energy-efficiency improvements and to pay through property taxes, allowing the lender to offer lower interest rates and to collect against future homeowners who also will benefit from the efficiency. *See Energy Department Releases Draft Updated Best Practices for Residential PACE Financing Programs*, U.S. Dep't Energy, July 19, 2016, http://energy.gov/eere/articles/energy-department-releases-draft-updated-best-practices-residential-pace-financing.
87. *See*, *e.g.*, Arik Levinson & Scott Niemann, *Energy Use by Apartment by Tenants When Landlords Pay for Utilities*, 26 Resource & Energy Econ. 51, 51-75 (2004). *See also* International Energy Agency, Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency (2007), *available at* http://www.iea.org/publications/freepublications/publication/mind_the_gap.pdf.
88. Murtishaw & Sathaye, *supra* note 85.
89. *Create a Residential "Green Lease Program,"* SPUR Urbanist, May 1, 2009, http://www.spur.org/publications/article/2009-05-01/critical-cooling/option-7.
90. *Id*.

Even if intermediaries do not create barriers, for many types of household equipment, consumers ultimately must be persuaded to buy more-efficient versions on a timely basis at the end of the useful life of existing equipment and then must use it in an optimal way. A deep body of research shows that consumers function with bounded rationality.[91] They act as if they hold high discount rates to future savings from efficiency and wrestle with the endowment effect, valuing what they have more than what they could obtain. They often wildly misestimate some aspects of the energy use and carbon emissions of equipment, underestimating by 40 times the energy use of clothes driers and overestimating by several times the benefits of idling rather than turning off a motor vehicle.[92] They can be deeply affected by the behavior of those around them, as work on descriptive norms has demonstrated.[93]

For some, personal values and norms provide motivation to purchase more-efficient or low-carbon equipment.[94] At the same time, such factors can also induce some people to take steps that are not in their pecuniary interest. For example, Republicans buy fewer efficient light bulbs if they are labeled as eco-friendly.[95] Similarly, cost savings may induce some to buy efficient equipment, but monetary incentives also have the potential to undermine the influence of personal norms.[96] As this discussion indicates, a complex mix of public and private laws, policies, and programs, often tailored to specific audiences, will be necessary to achieve rapid uptake of efficient equipment that would be readily purchased by an ideal, rational, and fully informed consumer.[97]

In addition to government programs, efforts by advocacy groups and other private actors can provide information or motivation for consumers to purchase and use more-efficient equipment. For instance, the private Project Porchlight campaign has reached thousands of households with information about energy efficiency and provided these households with more-efficient light bulbs, achieving substantial emissions reductions at a cost of roughly 1 cent per kilowatt hour (kWh) according to a study by the American Council for an Energy-Efficient Economy.[98]

Similarly, a number of large corporations have developed programs that subsidize employee investments in energy-efficient equipment.[99] An example is the large reinsurance company Swiss Re, which launched an employee program in 2007 called COyou2.[100] This program allows employees to claim subsidies for investments that include electric cars, public transport passes, energy-efficient home appliances, and solar panels. The subsidies cover 50% of investment costs up to a maximum of 5,000 Swiss Francs (roughly USD 5,000 as of writing).[101] In 2008, Sony Pictures launched a similar program, which offers subsidies to employees who purchase a qualifying hybrid or electric vehicle or who install photovoltaic solar panels.[102] Cisco Systems, Kimberly-Clark, and National Geographic have offered employee discounts on home solar electricity and efficiency.[103] Programs targeted at households are difficult to implement at a large scale, but some corporations have tens or hundreds of thousands of employees, making corporate employee programs a particularly promising area.[104]

2. Technology Use

In theory, as soon as efficient equipment is acquired or installed, a retail consumer will use the new equipment in a way that achieves the efficiency it can deliver. As the plug-in hybrid and other examples suggest, however, the literature

91. Daniel Kahneman et al., Judgment Under Uncertainty: Heuristics and Biases (1982).
92. Shahzeen Z. Attari et al., *Public Perceptions of Energy Consumption and Savings*, 107 Proc. Nat'l Acad. Sci. 16054, 16055 (2010); Amanda R. Carrico et al., *Costly Myths: An Analysis of Idling Beliefs and Behavior in Personal Motor Vehicles*, 37 Energy Pol'y 2881 (2009).
93. *See, e.g.*, Robert B. Cialdini, *Crafting Normative Messages to Protect the Environment*, 12 Current Directions Psychol. Sci. 105, 105-09 (2003); Carroll et al., *supra* note 78.
94. *See* Nicole M.A. Huijts et al., *Psychological Factors Influencing Sustainable Energy Technology Acceptance: A Review-Based Comprehensive Framework*, 16 Renewable & Sustainable Energy Rev. 525, 525-31 (2012). *See also* Charlie Wilson & Hadi Dowlatabadi, *Models of Decision Making and Residential Energy Use*, 32 Ann. Rev. Env't & Res. 169, 169-203 (2007).
95. *See, e.g.*, Dena M. Gromet et al., *Political Ideology Affects Energy-Efficiency Attitudes and Choices*, 110 Proc. Nat'l Acad. Sci. 9314, 9315 (2013). *See also* Doral L. Costa & Matthew E. Kahn, *Energy Conservation "Nudges" and Environmentalist Ideology: Evidence From a Randomized Residential Electricity Field Experiment*, 11 J. Eur. Econ. Ass'n 680 (2013).
96. *See, e.g.*, Uri Gneezy & Aldo Rustichini, *A Fine Is a Price*, 29 J. Legal Stud. 1, 1-17 (2000).
97. Clayton et al., *supra* note 77 (noting that information has greater impacts on behavior if it is tailored to the personal situations of consumers and resonates with values important to them, including place identity—people respond better when an action is shown to preserve a place important to them—and messenger—should be trusted by the community and seen as fair; and policies that reward rather than punish or curtail are more effective).
98. *See* Susan Mazur-Stommen & Kate Farley, American Council for an Energy-Efficient Economy, ACEEE Field Guide to Utility-Run Behavior Programs 27 (2013). *See also* EnWin Utilities, *Project Porchlight*, http://www.enwin.com/conservation/programs.project_porchlight.cfm (last visited Aug. 28, 2017).
99. Alexander Maki et al., *Employee Energy Benefits: What Are They and What Effect do They Have on Employees?* (under review 2017), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2801607.
100. Swiss Re launched the program with the help of Off4Firms, which specializes in designing employee programs, along with South Pole Carbon and Wageningen University. *See* Johannes Manser et al., Off4Firms, Accelerating CO_2 Emissions Reductions Via Corporate Programmes 7 (2013), *available at* http://www.off4firms.ethz.ch/wp-content/uploads/2012/04/Off4Firms-Working-Paper-2b-1.pdf.
101. Although the first five years only resulted in 4,000 investments, a few minor adjustments increased the investments to 1,700 in the sixth year of the program. On the whole, the program has been very popular among employees, although the carbon emissions reductions are unclear. *Id.* at 17.
102. Sony Pictures, *Employee Eco-Incentives*, http://www.sonypictures.com/green/act/employee-involvement/employee-incentives.php (last visited Aug. 28, 2017). Since the inception of the program, Sony claims that more than 300 employees have participated, resulting in savings of more than 200,000 gallons of gas and generating more than 500,000 kWh of clean power. Sony offers other incentives to employees who commit to a greener daily commute, including preferred parking, access to charging-enabled parking spaces, transit pass discounts, and secure bike racks. *Id.* In 2012, Sony launched a new interactive web-based platform called Practically Green, which provides small everyday activities employees can undertake to reduce their carbon footprints. Sony Pictures, *Small Acts: Greening Employees Everyday Actions*, http://www.sonypictures.com/green/act/employee-involvement/commit-acts.php (last visited Aug. 28, 2017).
103. Diane Cardwell, *Home Solar Power Discounts Are Worker Perk in New Program*, N.Y. Times, Oct. 23, 2014.
104. For a review, see Maki et al., *supra* note 99.

on the use of more-efficient equipment indicates that in practice, the equipment often does not achieve its intended efficiencies. The wide range of influences that affect technology uptake by households, including bounded rationality, information deficits, social and personal norms, identity, and worldview, also can affect the use of these technologies. In addition, various forms of take-back or negative spillover are a concern.[105] For example, a consumer may use the savings from a more-efficient air conditioner to run the air conditioner more. These negative effects on energy use often only amount to a small fraction of the savings achieved by the more-efficient equipment, however,[106] and we focus here on a greater concern: the failure by end-users to operate the equipment in optimal ways.

An example is the programmable thermostat, which holds the potential for increasing household energy efficiency, but programmable thermostats were so poorly used by consumers that they can no longer obtain an Energy Star label.[107] New technologies, such as the "Nest," a new "smart" thermostat acquired by Google, have attempted to account for human factors in a more sophisticated way, but the timing of adoption and use of these more user-friendly thermostats should be a cautionary tale for models that assume timely adoption of more-efficient technologies: more than a decade has passed since the first programmable thermostats became widely available, and the penetration of user-friendly thermostats into the household market remains limited, as does the efficient use of the wide range of thermostats that have been installed in the housing stock.[108]

3. Design Principles

Several types of laws, policies, and programs have the potential to improve technology uptake and use. Standard carbon pricing and regulatory schemes are important, but they may have less effect on consumer behavior than on the electric power, vehicle manufacturing, commercial building and operating, and industrial sectors. In addition, concerns about intrusion limit the ability of policymakers to regulate in the household and consumer areas.

In our view, the most promising approach for the household sector involves combining carbon pricing with nonregulatory public and private programs to overcome barriers to timely consumer adoption and optimal use of new low-emission technologies. Many programs have been attempted at the federal, state, local, and private levels. Rather than attempt to survey these programs, given the limited space available here, we have outlined above several design principles that characterize the most successful programs and that should be used in efforts to achieve deep decarbonization.

Many poorly designed behavioral interventions have failed, but some public and private initiatives have been remarkably successful in inducing behavior change on issues such as seat belt use, recycling, smoking, and the adoption of low-emissions energy technologies at the household level.[109] These successes and the research on interventions to reduce household energy use indicate that behavior shifts toward major reductions in carbon release may be feasible.[110] Behavioral intervention, appropriately designed, thus constitutes an important and effective tool that policymakers should use to address household energy use and carbon emissions.

E. Buildings

The timely uptake and optimal use of more-efficient new residential buildings and the weatherization of existing buildings can contribute important efficiency gains, and are an important aspect of the DDPP modeling. Successful programs in this area induce builders and remodelers to create more-efficient buildings and customers to purchase or rent them and use them in ways that will yield the modeled efficiency gains. A first option for increasing building efficiency at the state and local levels is adoption and enforcement of more-stringent efficiency requirements in building codes.[111] In addition, a number of government agencies have used nonregulatory programs to promote construction of more-efficient new buildings and weatherization of old buildings. For example, DOE has supported development not only of building codes, but also of energy auditing and disclosure systems for dwellings.[112] A variety of ongoing initiatives are also underway to promote weatherization, and the 2009 stimulus bill included a large funding boost for weatherization efforts in low-income communities.[113]

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105. *See* Kenneth Gillingham et al., *The Rebound Effect Is Overplayed*, 493 Nature 475, 475-76 (2013); Heather B. Truelove et al., *Positive and Negative Spillover of Pro-Environmental Behavior: An Integrative Review and Theoretical Framework*, 29 Global Envtl. Change 127, 128-32 (2014).
106. *Id*.
107. *See* ENERGY STAR, *Programmable Thermostats for Partners*, https://www.energystar.gov/products/heating_cooling/programmable_thermostats/partners (last visited Aug. 28, 2017).
108. Consumers have struggled to use programmable thermostats in ways that would yield the potential energy benefits. According to EPA, "[t]he ENERGY STAR specification for programmable thermostats was suspended on December 31, 2009 and the ENERGY STAR label is no longer available for this category. Manufacturers were required to cease using the ENERGY STAR name and mark in association with all products manufactured on or after December 31, 2009." *See* ENERGY STAR, *Programmable Thermostats Specification*, https://www.energystar.gov/index.cfm?c=archives.thermostats_spec (last visited Aug. 28, 2017).
109. Vandenbergh et al., *supra* note 23, at 10550.
110. *See* Dietz et al., *supra* note 1, at 1843-45.
111. U.S. Department of Energy, *Building Energy Codes Program—Regulations & Rulemaking*, https://www.energycodes.gov/regulations (last updated July 28, 2014). *See also* ASHRAE, *Standard 90.1*, https://www.ashrae.org/resources--publications/bookstore/standard-90-1 (last visited Aug. 28, 2017); International Code Council, *International Energy Conservation Code® Resource Page*, https://www.iccsafe.org/about-icc/government-relations/international-energy-conservation-code-resource-page/ (last visited Aug. 28, 2017).
112. *See* U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *About Building Energy Codes*, https://www.energycodes.gov/about (last updated Nov. 18, 2017); *see also* U.S. Department of Energy, Better Buildings, *About the Home Energy Score*, https://betterbuildingssolutioncenter.energy.gov/home-energy-score/home-energy-score-about-score (last visited Aug. 28, 2014).
113. American Recovery and Reinvestment Act of 2009 §5(b) div. A, tit. IV, sec. 1705, 42 U.S.C. §§6861 et seq.

Public and private home energy rating systems can create incentives for home builders to build more-efficient homes and to install more-efficient equipment, and for existing homeowners to weatherize and upgrade equipment. Research suggests that higher-rated homes are associated with higher home values.[114] Public and private home energy rating systems seek to increase the likelihood that homeowners will recoup investments in efficient HVAC systems, water heaters, and other long-term home efficiency investments.[115] These systems encourage sellers of new and existing homes to post home energy-efficiency data, such as in the widely used home multiple listing services (MLS). MLS systems facilitate the majority of real estate transactions within the United States, and thus far, more than 125 MLS systems have implemented green data entry fields to increase realtor access to green property data.[116] The inclusion of green data in the MLS should allow for more accurate assessments of property values and facilitate consumer interest in efficiency in the real estate market.

Labeling of rental units as energy-efficient is a potential strategy for changing the market for rental units. More research is necessary to assess the effects of rental unit energy disclosure, but the early results are promising. For instance, in a recent experiment, potential short-term renters through Airbnb were willing to pay an additional $6.65 per night for units certified with an energy-efficiency label, an amount that could motivate owners to invest in efficiency.[117]

In the past decade, increased use of private certification standards for new and renovated buildings has encouraged increased efficiency.[118] An example is the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) for Homes program, a private standard and certification system that verifies the energy efficiency of a property and estimates cost savings for potential homebuyers.[119] Standardized labeling and certification programs can provide information to realtors and homebuyers unfamiliar with energy-efficient features, although these programs are not yet available for many homes. According to the National Association of Realtors, approximately 20% of newly constructed homes are green projects, and these homes tend to sell for 5-10% more than traditional homes.[120]

Although certification systems typically focus on rewarding high-performance new homes, these homes only represent a small percentage of all homes in the United States, with existing homes and homes not catering to the high-efficiency market making up the bulk of the housing stock in any given year. As a result, a simple disclosure in MLS rankings of the energy efficiency of each listed home, whether new or existing, and whether high-performing or not, has the potential to reach far more homes than one targeted only at high-performance homes.[121] By creating widespread market incentives to invest in energy-efficient equipment and to use existing equipment more efficiently, home energy disclosure initiatives have the potential to reach households at large scale and to yield prompt, large emissions reductions.[122]

F. *Motor Vehicles*

The DDPP modeling also envisions a major transition to light-duty electric vehicles in the near term and heavy-duty electric vehicles in the long term. In the absence of a carbon price, the federal government has driven recent reductions in carbon emissions through increasingly stringent Corporate Average Fuel Economy (CAFE) requirements for motor vehicle fleets.[123] These standards push automakers to increase the proportion of electric vehicles in the motor vehicle fleet, and increasingly stringent new CAFE standards in theory could accomplish the transition to electric vehicles envisioned by the DDPP modeling. In addition, other options are available, such as those created by the federal government's settlement with Volkswagen regarding nitrogen oxide emissions detection defeat devices on diesel cars. The settlement created new incentives for a shift toward electric motor vehicles,[124] and additional opportunities may arise in the

114. *See* Sharon Shewmake & Kip Viscusi, *Produce and Consumer Responses to Green Housing Labels*, 53 Econ. Inquiry 681 (2014) (discussing results of study of effects of home energy ratings on home prices).

115. *See* Matt Pearce, *Highlighting Green Homes by Greening the MLS*, U.S. Green Building Council, Feb. 24, 2012. *See also* Elevate Energy, *Value for High Performance Homes*, http://www.elevateenergy.org/value-high-performance-homes (last visited Aug. 28, 2017).

116. *See* National Association of Realtors, Green MLS Implementation Guide 9 (2014), http://greenresourcecouncil.org/sites/default/files/2014%20NAR%20Green%20MLS%20Implementation%20Guide.pdf.

117. *See* Steven C. Isley et al., *Online Purchasing Creates Opportunities to Lower the Life Cycle Carbon Footprints of Consumer Products*, 113 PNAS Early Addition 9780, 9783-86 (2016). *See also* Danielle Speigel-Feld, *New York City Should Grade Buildings on Energy Efficiency*, N.Y. Times, June 5, 2017, at A21, *available at* https://www.nytimes.com/2017/06/05/opinion/new-york-buildings-energy-efficiency.html?mcubz=1.

118. *See* U.S. Green Building Council, *Guide to Certification: Homes*, https://www.usgbc.org/cert-guide/homes (last visited Aug. 28, 2017).

119. Roughly 20% of newly constructed homes are green projects, and green homes tend to sell for 5-10% more than traditional homes. National Association of Realtors, *supra* note 116, at 72.

120. *Id*.

121. *See* MetaResource Group, Home Energy Performance Scores: Efforts to Date With Modeling Tool Comparison and Summary of Key Issues 3 (2012).

122. For instance, looking only at manufactured homes (often called "mobile homes"), energy-use labeling could reveal opportunities to save money on energy bills and reduce emissions. A typical manufactured home could achieve net savings of $279 per year (accounting for the cost of energy-efficient construction), with total national net savings of $1.7 billion dollars per year and a reduction of 23 million tons per year of CO_2 if all buyers of new and used manufactured homes took advantage of energy-efficiency measures that produced net savings. *See* Jacob Talbot, Mobilizing Energy Efficiency in the Manufactured Housing Sector (American Council for an Energy-Efficient Economy, Research Report A124, 2012), www.aceee.org/research-report/a124.

123. For a discussion of the agency interactions that generated recent CAFE standards, see Jody Freeman & Jim Rossi, *Agency Coordination in Shared Regulatory Space*, 125 Harv. L. Rev. 1131 (2015).

124. Camille von Kaenel, *Conservatives to Obama: Don't Use VW Settlement to Push EVs*, ClimateWire, Aug. 8, 2016 (describing the settlement with Volkswagen as involving "a $2 billion pot of money for electric vehicles" and noting that "[u]nder the settlement, Volkswagen is required to submit a plan to invest in EV [electric vehicle] charging stations, public education and electrifying large fleets like those of ride-sharing networks"), https://www.eenews.net/climatewire/stories/1060041300/; *see also* Ariel Witten-

future for the use of enforcement actions to increase the speed and extent of the transition.

These regulatory and enforcement initiatives are directed at vehicle manufacturers, and although they can force manufacturers to offer electric or other low-carbon vehicles, this approach will fail unless consumers buy the vehicles. To that end, the federal response has included using state-of-the-art behavioral science to redesign the information or label required to be displayed on every vehicle.[125] This response has been constrained by legal requirements regarding the information that must be on the label.[126] The resulting label better reflects behavioral science insights, but much remains to be done to produce the most effective label and other communications regarding fuel efficiency. Doing so may require changes in the law to provide flexibility to agency staff, however, and a willingness of agencies to incorporate social and behavioral science knowledge into labeling and other agency actions.

Private governance responses and collaborative responses also can drive the transition to electric vehicles or other low-carbon vehicles, as well as shifts in the use of motor vehicles. As to the motor vehicle manufacturers, investor and lender pressure on vehicle manufacturers, such as efforts by CDP (formerly named the Carbon Disclosure Project), Ceres, and other private organizations, can complement formal legal incentives for the manufacturers to produce and market low-carbon vehicles.[127] Fleet buyers, ranging from the federal government to corporations that purchase large vehicle fleets, can exert pressure on vehicle manufacturers to reinforce these incentives.[128]

Private initiatives also can increase the uptake of lower-carbon vehicles by retail consumers. The private actors discussed above can not only press manufacturers to make new vehicles, but also to market the lowest-carbon vehicles more aggressively. In addition, although general public information campaigns by advocacy groups typically have only limited effects on consumer behavior, targeted efforts to provide information at the point of decision (e.g., via the Internet) may be more promising.

Although ensuring the supply and uptake of low-carbon vehicles is the most critical role that laws, policies, and programs can play, these measures also can increase the extent to which individuals and organizations use vehicles efficiently. So long as vehicles emit some carbon, either directly or through the generation of the electricity or other fuel for the vehicle, efficient use is an important element of deep decarbonization. As the behavioral wedge chart (Table 1) indicates, actions ranging from adjusting tire pressure to other forms of maintenance to avoiding jackrabbit starts and other changes in driving styles affect emissions from motor vehicles. The example we presented earlier of individuals not using the plug-in function on their plug-in hybrid cars is a good example of the need to account for behavior in the use of more-efficient technologies.

In addition, energy myths (widely held erroneous beliefs) may lead to inefficient use. For example, on balance, individuals think they should idle their vehicles for far longer than they should if the goal is to save money and fuel and decrease carbon emissions. This idling behavior generates millions of tons of carbon emissions each year—as much as important industry sectors.[129] Until the motor vehicle fleet includes widespread use of automatic devices to control idling, efforts to address this myth could provide significant emissions reductions and enable vehicles to achieve their modeled emissions. Many options, including local ordinances, immediate fuel use feedback on the dashboard, inclusion of "green driving" concepts in driver education programs, and others, are available to respond to idling and other vehicle use and maintenance issues.

On the surface, self-driving vehicles may appear to be the answer to the challenge of inefficient use of vehicles, but research indicates the need for more attention to behavioral issues regarding these cars, too. In a 2016 study, researchers at the University of Michigan found that consumer responses to self-driving vehicles may not lead to optimal use of the vehicle.[130] For example, many users report that they would not purchase such vehicles. Or, if they did, they would constantly oversee the vehicle's operation, and so might not allow it to operate in the most fuel-efficient manner if the self-driving operation did not correspond to the driver's own preferences or habits. These concerns may be overcome in the near future, but they provide yet another example of the need to account for behavior when developing laws, policies, and programs to achieve deep decarbonization, rather than to assume that when a less costly alternative is available, it will be adopted in a timely fashion and used as intended.

G. *Ways Forward*

As we mentioned earlier, the most promising behavioral initiatives can be identified by determining which proposals maximize the product of technical potential, behavioral plasticity, and policy plasticity or initiative feasibility.[131] The design principles discussed above

berg, *Trade Group Ignites Debate Over "Clean Diesel" Label*, GreenWire, Aug. 5, 2016 ("As it is currently proposed, the $2.7 billion mitigation fund would be distributed to the states . . . Leaders could use the money to foot 75 percent of the bill of a new electric commercial vehicle, but just 25 percent of the cost of a new diesel vehicle."), https://www.eenews.net/greenwire/2016/08/05/stories/1060041276; *see also* Camille von Kaenel, *Volkswagen and U.S. EPA Have a Deal, but No Fix*, ClimateWire, June 29, 2016 ("The proposed deal . . . sets aside $10 billion for compensating drivers . . . Another $2 billion would go toward improved access to electric vehicles."), https://www.eenews.net/climatewire/2016/06/29/stories/1060039582.

125. *See* Cass R. Sunstein & Hunt Allcott, *Regulating Internalities*, 34 J. Pol'y Analysis & Mgmt. 698 (2015).
126. 49 U.S.C. §32905; 49 U.S.C. §32908; 40 C.F.R. §§600.301-600.316-08 (2011); 40 C.F.R. §85.1510 (2011).
127. *See* Vandenbergh & Gilligan, *supra* note 10, at 253.
128. For a discussion of supply chain pressure regarding carbon emissions, see *id.* at 273-74.
129. Carrico et al., *supra* note 92 (discussing idling myths); Attari et al., *supra* note 92 (identifying other household myths involving energy use).
130. Michael Sivak & Brandon Schoettle, University of Michigan Sustainable Worldwide Transportation, Would Self-Driving Vehicles Increase Occupant Productivity? (2016).
131. Vandenbergh & Gilligan, *supra* note 10; Stern & Vandenbergh, *supra* note 10.

point to possibilities for advancing decarbonization goals. Many of these possibilities arise from the uptake of more-efficient household, building, and transportation technologies, but some arise from the use of existing and new technologies.

It is important to emphasize that the policy actors that are best positioned to initiate or collaborate in developing and implementing behavioral initiatives are best determined by considering which ones can best implement the design principles. Federal governmental entities are well-positioned to lead with some initiatives, as they have done, for example, with energy labeling of mass-marketed consumer products. However, sub-federal governmental authorities or private, nongovernmental actors are often as well- or better-positioned to develop certain initiatives that implement the design principles. Sometimes, collaborations among different types of entities will be advisable for designing effective interventions. For example, when industry groups take initiatives that can help them market their emissions-reducing products, they will need to address consumer credibility challenges to their information and performance claims. Collaborations with independent, nonindustry entities with known, impartial credibility hold promise for addressing such challenges.

In the domain of home equipment, the following strategies that target increased uptake of more energy-efficient technologies deserve more widespread implementation, with evaluation efforts to identify the most effective ways of implementing them:

- Green leases, which allow landlords to benefit from investing in more energy-efficient equipment, for example by modifying rent control rules to allow investment costs to be recouped in higher rents.
- Improved life-cycle cost information for retailers, who can use it to show the lower life-cycle cost of efficient equipment to customers at point of purchase.
- Improved life-cycle cost information for householders at point of purchase, for example with online databases accessible through cell phone technology in stores or equipment labels.
- Employer partial subsidies for employees' energy-efficient equipment purchases, justified as a benefit of employment or an indication of management concern for employees' quality of life.
- Collaborations between equipment manufacturers and nonprofit organizations (e.g., environmental groups) to provide highly credible life-cycle cost information.
- Low-interest loan programs for energy-efficient equipment operated by electric utility companies to avoid costs of new power plant construction.

In the domain of increasing the uptake of energy-efficient buildings, these strategies deserve further use, testing, and evaluation:

- Energy audits of existing homes to enable energy rating, certification, or labeling systems and/or MLS posting of green data to incentivize owners with potential higher resale value and mortgage lenders to lend more if operating costs are lower.
- Energy rating systems for new homes to accomplish the same purposes by incentivizing builders.
- Independent labeling of energy efficiency of rental units by impartial sources to incentivize landlords to invest in energy efficiency in anticipation of receiving higher rents.

In the domain of reducing carbon emissions from the use of existing and new home equipment and buildings, these strategies deserve further use, testing, and evaluation:

- Provision of monthly feedback with comparative data to harness efficiency and social norm motivations for reducing energy use.
- Provision of immediate feedback devices in homes to enable individuals to monitor and reduce energy use.
- Implementation of information campaigns and organizational efforts to promote filter replacement, thermostat setback, and other energy use reduction actions.

In the domain of motor vehicle efficiency, these strategies deserve further use, testing, and evaluation:

- Development and testing of improved energy labeling on new vehicles, especially hybrid and electric vehicles.
- Use of supply chain pressure by vehicle fleet buyers to incentivize manufacturers to develop and improve performance of low- or zero-carbon emissions vehicles.
- Improved life-cycle cost information for consumers at point of purchase, similar to what can be done with home equipment.
- Testing of consumer acceptance of self-driving vehicles and identifying barriers to optimal operation of these vehicles.
- With new technologies such as alternative fuel and self-driving vehicles, targeted marketing to environmentally minded and innovation-seeking consumer segments.

In the domain of reducing carbon emissions from the use of existing and new motor vehicles and other forms of transportation, these strategies deserve further use, testing, and evaluation:

- Provision of immediate fuel use feedback devices in vehicle dashboards to enable individuals to monitor and reduce fuel use and carbon emissions.

- Development of eco-driving education programs to promote fuel-efficient, low-carbon behaviors (e.g., tire inflation, filter replacement, avoidance of idling, and jackrabbit starts).
- Development of new technologies and information campaigns to promote mass transit use.

Other important classes of consumer behavior, particularly adoption of household-level renewable energy systems (type R behavior) and purchases of products with low life-cycle emissions (type L), can also be advanced by application of insights about consumer behavior. The design principles described above appear to be applicable to type R behaviors,[132] and support these promising strategies:

- Informal marketing through neighborhood and social networks.
- With new technologies, targeted marketing to environmentally minded consumers.
- Provision of credible information, such as performance data from nearby installed systems, at points of marketing and decision (e.g., community-based informational/marketing events).
- Design of marketing to minimize consumers' informational needs and provide quality assurance (e.g., sale or lease arrangements in which the seller guarantees performance, obviating the need for consumers to evaluate renewable energy products and the systems connecting them to home or grid).

To promote purchases of products with low life-cycle emissions, the most critical challenges involve developing and providing credible life-cycle emissions information at point of purchase along with other kinds of product information that are more generally available. We note, though, that border allowance and other aspects of carbon pricing measures also face this challenge.

VI. Beyond the DDPP Analysis

Although the DDPP analysis provides a rigorous quantitative demonstration of how increased efficiency along any of four pathways could lead to 80% emissions reductions by 2050, it is unlikely that every aspect of the technological and behavioral shifts anticipated by the DDPP analysis will occur. Additional behavioral initiatives may be necessary to fill gaps that arise along the way. In other words, in addition to the technology and behavior changes included in or assumed by the report, policymakers would be smart to pursue additional measures to provide insurance for the inevitable shortfalls that will occur in planned changes. To that end, an important next step is to identify behavior-based changes that could supplement those presumed in the DDPP analysis and to identify the laws, policies, and programs that could achieve the emissions reduction potential of these behavior changes.

Some of these changes are implied above in our discussion of programs that likely go beyond what is anticipated within the DDPP. Examples include efforts to remove split incentive barriers, such as between landlords and tenants in rental housing and between producers, retailers, and consumers in product and service supply chains, and thus achieve emissions reductions that no single actor in these relationships has incentives to achieve. Institutional changes, for example to allow community-based photovoltaic systems and thus enable them to serve homes that are not otherwise well-suited to install their own photovoltaic systems, may go beyond the DDPP in a similar way. In this section we examine two other domains where emissions reductions beyond the DDPP are achievable: reducing energy use without increasing efficiency and facilitating transitions to lower emissions lifestyles.

A. *Reducing Demand for Energy Services*

The DDPP modeling includes large increases in efficiency, but it does not include reductions in the demand for energy services to achieve emissions reductions.[133] Final energy demand is reduced in all cases due to the increased efficiency of delivering those services (e.g., electric versus internal combustion engine vehicle), but the modeling enables deep decarbonization to occur without overall reductions in the demand for energy services. This is an attractive approach, since it enables the DDPP initiative to demonstrate that deep decarbonization can occur with a minimum of social or economic disruption, maintaining business as usual in terms of the growth of population and energy services demand.

Nevertheless, a number of policy options are available to reduce demand for energy services, not just to reduce the energy needed to supply those services, and some demand reduction initiatives are viable near-term options. Many of the behavioral wedge actions identified in Table 1 fit into this category: they are not already included in the DDPP modeling but could yield important additional emissions reductions. In this light, a full accounting of the contribution that behavior change can make to deep decarbonization should address not only adoption of more efficient technologies, but also behaviors that reduce the demand for energy by reducing wasted energy—for example by reducing motor vehicle idling, adjusting HVAC thermostats and turning off lights when these services are not being used, or ensuring that the temperature setting on a water heater is not above the level necessary for comfortable water use. Such reductions in energy use can cut emissions without reducing the welfare or well-being of the individuals expected to take these steps. They vary in behavioral plasticity, but they do not require major new capital investments, in contrast to many technology adoption measures.

132. Wolske & Stern, *supra* note 4.

133. The DDPP assumes large increases in efficiency, but not from change in the use of existing equipment.

Although some reductions in energy use with existing equipment do, in fact, reduce desired energy services (e.g., making people uncomfortably cold indoors in winter), others do not. The most visible example of the latter is turning off lights in rooms not in use. The behavioral wedge analysis presented in Table 1 labels such actions A (for adjustment), and lists two: resetting water temperatures and laundry temperatures so as not to be above what the household needs. There are other examples, some of which have become more feasible since that 2009 behavioral wedge analysis because of technological advances. For example, many European hotel rooms require insertion of room key cards in a slot to allow lights and televisions to come on. This eliminates usage when the room is unoccupied without reducing energy services. Similarly, remote operation of home equipment can enable occupants to condition the space only when it will affect their comfort, and not when they are away for extended periods. Other examples include better routine maintenance of HVAC systems and motor vehicles and some changes in driving behavior.

Such behavior changes are not already included in the DDPP modeling but could yield important additional emissions reductions. These actions vary in behavioral plasticity, but they do not require major new capital investments, in contrast to many technology adoption measures. As the behavioral wedge analysis suggests, these classes of behavior have realistic potential to add to emissions reductions in the near term, beyond DDPP estimates. The additions are relatively small, but if they are maintained, they have the advantage of faster start-up than technology adoption. They also have the advantage of requiring little or no up-front financial investment, and initiatives targeting these behaviors may be easier to adopt and implement than many technology adoption initiatives.

Finally, some changes in the use of existing technology are widely perceived by current populations as reducing well-being: reducing heating, cooling, and lighting below comfort levels; carpooling; replacing car transport with less-emitting travel modes; and so forth. Such changes are likely to be widely resisted in the near term because they feel like sacrifice. They are unlikely to produce sizable emissions reductions unless they are adopted as temporary responses to emergencies or there are changes in social norms, lifestyles, or ideas of well-being, such as a more widespread belief that bicycling and walking have health benefits that compensate for time spent or are signs of a good community. We discuss such lifestyle and normative changes below.

B. Enabling Lifestyle Transitions That Lower Emissions

The DDPP explicitly omits lifestyle change from its analysis, which simplifies the modeling and provides a reasonable, viable approach to understanding how a deeply decarbonized energy system could function in 2050. However, lifestyles will change. They have changed dramatically in the past generation or two, and they will change further in the generation or two between now and 2050—in ways that may be affected by decarbonization strategies, policies, and programs.

Since World War II, major shifts in lifestyle have occurred, many brought about by developments in technology, demography, economy, and infrastructure. Many of these shifts have strongly influenced carbon emissions: movement to the suburbs; increases in airplane travel; increases in the percentage of people living in single-household houses and living alone; increases in home size; and changes in daily habits resulting from widespread adoption and use of refrigerators, microwaves, televisions, cars, computers, and cell phones. Successful decarbonization will depend on how lifestyle will change by 2050 and beyond, so lifestyle must be considered in a complete analysis of decarbonization pathways and in policy. Recent history also demonstrates a wide range of areas outside of energy use that have seen major lifestyle shifts—in some cases, partly in response to deliberate efforts to bring these changes about. Examples include decreases in smoking, increases in seatbelt use, and shifting views on civil rights—involving women, the LGBTQ community, and African Americans.

Even though generational-scale lifestyle changes are difficult to model, public and private policymakers need to be attentive to them in two ways: playing offense, particularly when policymakers confront forks in the road where some lifestyle shifts could facilitate deep decarbonization, and playing defense by heading off lifestyle shifts that could undermine deep decarbonization. As we mentioned at the outset, forks in the road may be particularly important for lifestyles and other aspects of behavior, since beliefs and habits are very difficult to change once they are adopted and tend to stick within the generation of people who develop them. For instance, a generation of conservers, shaped by the Great Depression and World War II, was replaced by a post-war generation of consumers.

It may be possible, without such national traumas, to facilitate lifestyle changes in the next generation that will have similarly long-lasting effects. Possibilities might include the development of the sharing economy in ways that reduce carbon emissions, such as through car sharing or community solar energy production. Socially acceptable policies and programs might be devised that promote movement into urban cores; small shifts in diet; walking and bicycling as alternatives to car transport for some trips; and shifts to virtual communication as a substitute for social and work travel, all of which could yield major additional carbon emissions reductions.[134] Some of these changes in habits and in supporting social norms may already be appearing in segments of the generation now in their 20s and 30s.[135]

134. Sharon A. Shewmake et al., *Predicting Consumer Demand Responses to Carbon Labels*, 119 Ecological Econ. 168, 168-80 (2015). *See also* Jeremy Deaton, *China's New Dietary Guidelines Could Be Good News for the Climate*, ThinkProgress, May 24, 2016, https://thinkprogress.org/chinas-new-dietary-guidelines-could-be-good-news-for-the-climate-f385f9388f72.

135. *See, e.g.*, Sara E. Light, *Precautionary Federalism and the Sharing Economy*, 66 Emory L.J. 333 (2017) (discussing environmental implications of the sharing economy).

As to playing defense, public and private policymakers should be aware of lifestyle changes that could undermine the effort to achieve deep decarbonization. An example of lifestyle-type changes that could undermine decarbonization is the possibility of increasing settlement in exurban areas and the resulting increases in commuting, house sizes, and other emissions-creating practices, all of which are baked in for the lifetime of the new communities and infrastructure. This shift also could affect the norms of generations raised in those environments. In seeking deep decarbonization, policymakers should consider such effects, even if they cannot be modeled with precision.

The transition to an Internet-based consumer marketplace marks lifestyle changes that could not only reduce carbon emissions (e.g., from shopping trips), but also increase emissions if shipping, packaging, and consumption patterns become more carbon-intensive. If consumers continue to adopt Internet-based shopping but routinely opt for overnight shipping, the carbon footprint will be much larger than if opting for one-week shipping becomes a habit. The use of Internet technologies to disclose carbon emissions from shipping and other aspects of product and service life cycles, to reduce demand for overnight shipping, and to automate and aggregate small purchases of carbon offsets that would otherwise require too much effort from consumers, could create a less carbon-intensive retail process and represent an important fork in the road for policymakers.[136] Technologies and behavioral practices that become entrenched in the near term have their own momentum and may either promote or undermine deep decarbonization efforts.

VII. Conclusion

Why does behavior matter for deep decarbonization? Our first answer is that a great deal of behavior change is assumed in the annual efficiency improvements that are included in the EIA annual energy projections that form the starting point for each of the four DDPP pathways, and in the projected efficiency enhancements included in the pathways. Although the DDPP report does not include a case or scenario that involves explicit behavioral interventions designed to reduce individual or household carbon emissions or to increase the supply of low-carbon energy from these sources, behavior change regarding energy supply and demand is assumed to occur. The behavior change occurs mainly in the form of timely uptake and optimal use of new, more-efficient technologies at the end of the useful life of items: actions ranging from acquisition of more energy-efficient buildings to consumer goods such as light bulbs, water heaters, and HVAC systems. Behavior change is also assumed to occur in the acceptance of new technologies, whether windmills, nuclear power plants, or CCS facilities.

The depth of the behavior change necessary to achieve 80% emissions reduction by 2050, along with substantial reductions in the near term, indicates that it is very possible, perhaps likely, that the DDPP pathways on their own will not achieve deep decarbonization. Because behavior often does not conform to standard assumptions about the uptake and use of more-efficient technologies, failure to attend to these behavioral deviations from the assumptions may mean that the implementation of the pathways will be delayed or incomplete and that greater reductions may be necessary than projected. How can laws, policies, and programs that target behavior change be employed to facilitate decarbonization?

Fortunately, the social and behavioral science literature on energy and environmental behavior has made remarkable progress in the past several decades.[137] It is now up to public and private policymakers to incorporate the insights of this literature into laws, policies, and programs directed at deep decarbonization. We have provided an initial analysis here, but we conclude that more-extensive analyses should consider the role that specific types of behavior change must play to achieve the four pathways and the complementary role that behavior change can play to supplement the pathways.

Further work also should take a broad view of which institutional actors are in the best position to promote the behavior change necessary for deep decarbonization. This effort should not simply consider government adoption and implementation of the laws, policies, and programs that are often identified for climate mitigation (e.g., federal and state carbon taxes or cap-and-trade systems, and state efficiency standards for vehicles and appliances). To achieve the deep and prompt emissions reductions envisioned by the deep decarbonization effort, we suggest a concerted effort to identify the optimal mix of public and private standards, policies, and programs, including those initiated by nongovernmental organizations, corporations, religious organizations, and others. These private governance activities are likely to be necessary both to enable governmental efforts to achieve their intended targets, and to achieve additional emissions reductions in the event that governmental efforts fall short or current emissions reduction targets prove to be inadequate.[138]

136. *See* Isley et al., *supra* note 117.

137. For reviews, see Stern et al., *supra* note 6; Vandenbergh & Sovacool, *supra* note 1; Osbaldiston & Schott, *supra* note 65.

138. Vandenbergh & Gilligan, *supra* note 10; Stern et al., *supra* note 6.